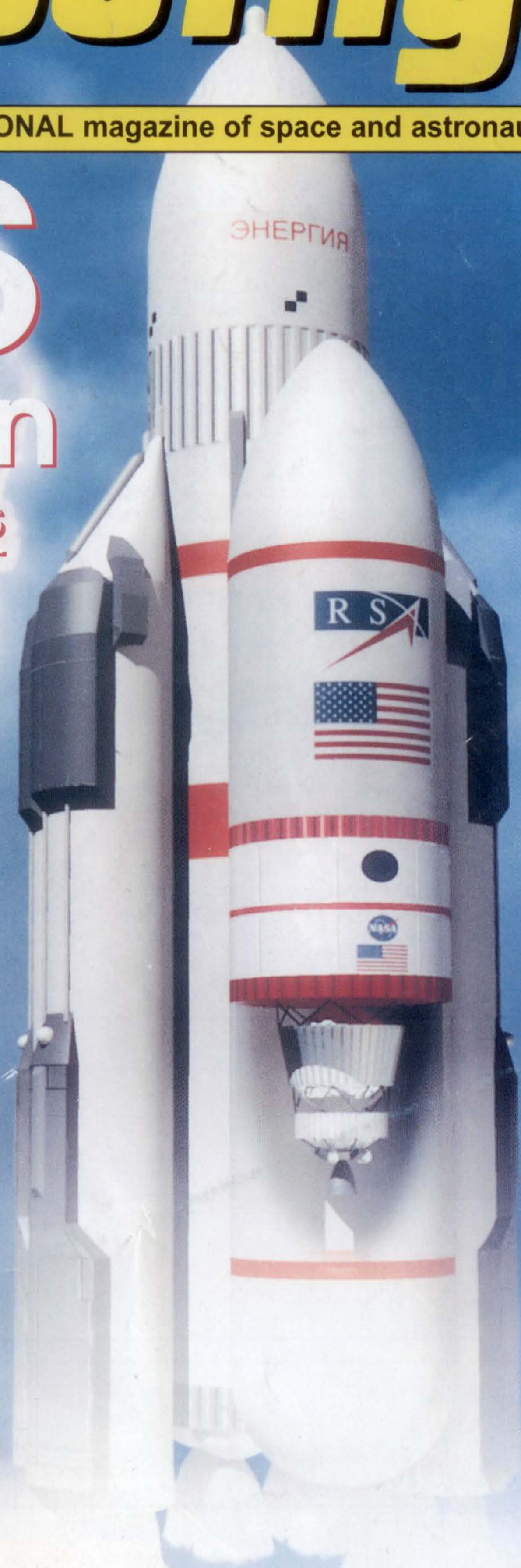
Vol. 39 No. 12 1997 £2.20

Spaceflight

The INTERNATIONAL magazine of space and astronautics



MARS Exploration

- A Decade of Probes
- Crewed Missions

Mir Station

Foale's Vital Role

Module Rupture Mystery

Last Voyage to the Moon

APOLLO 17

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WWW: http://freespace.virgin.net/bis.bis/bis.htm

DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by COMAG Specialist Division, Tavistock Works, Tavistock Road, West Drayton, Middlesex UB7 7QX. Tel 01895 433800, Fax 01895 433801 and in the USA by ADS International, 3400 Dundee Road, Northbrook, IL 60062, USA.

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Back issues of ***Spaceflight*** are supplied at £3.00 (US$6.00) each, inclusive of surface mail delivery. ***Spaceflight*** binders (holding 12 issues) are available at £8.50 (US$17.00), inclusive of surface mail delivery.

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Published monthly by the **British Interplanetary Society**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Registered Company No: 402498. Registered Charity No: 250556. Printed in the UK by Newman Thomson Limited, 13 Albion Street, Brighton BN2 2NE.

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Published By The British Interplanetary Society
Vol. 39 No. 12 December 1997

CONTENTS

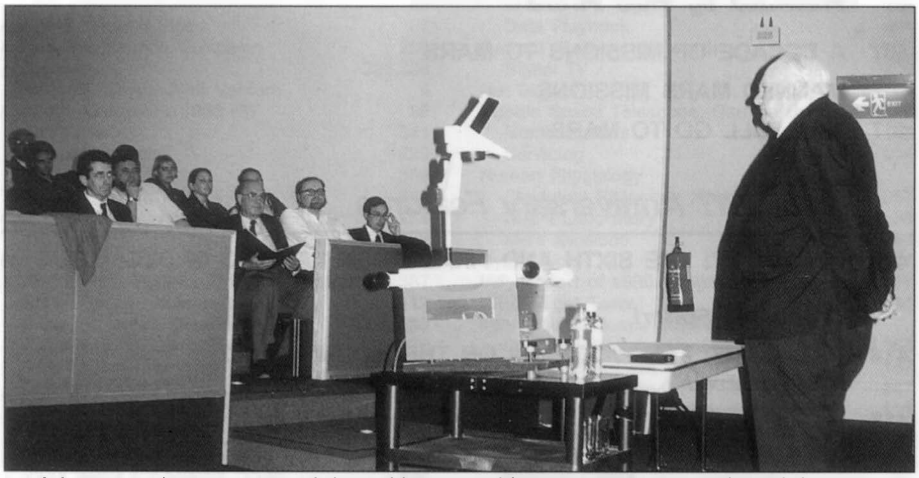
Front Cover: **The lift-off of a heavy launch vehicle to place up to 240 tons in Low Earth Orbit is depicted as the first stage of a manned mission to Mars. The reference plan to be proposed to NASA and the international community for manned missions to Mars includes consideration of a modified Energia launch vehicle. See 'Manned Mars Missions', p.408.** NASA/JSC

BIS News

Sputnik 1 Launch Celebrated

Patrick Moore Receives Society's Medal

A joint meeting arranged by the BIS and the Science Museum on 4 October 1997 was held at the Museum to celebrate the launch of Sputnik 1 forty years ago. The meeting attracted a large audience of members of the Society and their guests and was opened and chaired by Rex Hall.



Patrick Moore gives an entertaining address touching on many personal reminiscences.

Nick Johnson, Chief Scientist for orbital debris at NASA was the first speaker in the morning session and spoke on "40 Years of Earth Satellites" and the pattern of future launches. He reviewed the scale of launches since the start of the space age and its effect in terms of debris present in the near-Earth environment, debris which ranged from large items such as old rocket bodies to at least a million flecks of paint. He looked ahead to how this will affect future work and what steps are being taken to protect future missions such as the International Space Station.

The next presentation was an overview of the Russian and Chinese Space programmes given by Phil Clark of Molniya Space Consultancy. Dividing these programmes into their various mission classifications highlighted the range of operations undertaken by both countries.

The next event was the screening of the film 'Ten Years in Space'. As this was made in 1967 to celebrate the 50th Anniversary of the October Revolution, the chairman reminded the audience that, although it was a film of its time and designed to convey propaganda, it showed - for the first time - a number of key events in the early days of the exploration of space. It was only at the Paris Air Show that same year that the R-7 booster was shown for the first time.

The afternoon session began with Mark Hempsell, President of the Society, making the presentation of the Society's Space Achievement Medal to Dr Patrick Moore CBE, thus celebrating a contribution unique to space in this country. Dr Moore, who has been a Fellow of the Society for over 40 years, had advised NASA on lunar mapping for the Apollo programme and assisted on various Mars initiatives. After the presentation Patrick gave a talk about his life and career

Patrick Moore (right) receives the Society's Space Achievement Medal from Mark Hempsell, the BIS President.

which contained many personal reminiscences and amusing recollections.

The last speaker was Gordon Bolton, who had spent much of his career at the European Space Agency and who looked at the success of the Spacelab project and its contribution to space exploration.

After a short question and answer session concerned with the future of British contributions to space, the Chairman thanked those present for coming to this jointly sponsored meeting between the BIS and the Science Museum and invited them to take the opportunity to tour the Museum, particularly its Space Exploration section.

Mars, In Two Volumes

The Society is pleased to announce that members now have the opportunity of obtaining selected papers on the Exploration of Mars from recent issues of *JBIS* which have been grouped together for easier presentation in two volumes.

A 20% discount is available to members of the Society on purchase of these volumes in either hardback or softback from Univelt.

Fuller details appear on page 430 of this issue.

BIS Lecture on. . .

New Approaches to Design of Flight Projects

At the Society's evening lecture on 1 October 1997, William I. McLaughlin of the Jet Propulsion Laboratory gave a description of new approaches to greatly reduce the time and cost required to bring a space project to maturity.

A major objective of JPL's re-engineering is to cut the development time for a flight project by a factor of two. Two principles of the new process are the use of concurrent design and extensive reliance upon computerised modelling and simulation.

Concurrent design for proposals and other early-phase studies has been very successfully undertaken by The Advanced Projects Development Team, "Team X", which operates out of the Project Design Center. This concurrency is achieved through mission, system, subsystem and costing personnel of Team X working together in one area and through integrated software and data bases for team members to utilise at their workstations. Development costs have dropped dramatically through the use of Team X.

The use of modelling and simulation continues to grow as additional subsystem models (power, telecom, etc.) are completed. A "Team I" (instruments) has been formed and other portions of the development process are being addressed.

OBITUARIES

We regret to record the death of ERIC WILLIAM TROMAN (Fellow) at the age of 77. Mr Troman, who joined the Society in 1954, was formerly a Senior Technical Assistant in the Development Department of Normal Air Ltd at Yeovil where he was concerned with developing engines, both gas turbines and rocket motors, besides high altitude equipment for breathing purposes.

We regret to record the death of MALCOLM ANDERSON POWELL (74), a Fellow of the Society for 32 years.

Mr Powell was educated at University College, Cardiff and was closely concerned with the organisation of trials for Black Knight, Skylark and Blue Streak at the Woomera Range in South Australia. He was seconded to WRE by the Ministry of Aviation as Assistant Blue Streak Staff Officer, British Defence Research and Supply Staff and later became Senior Experimental Officer on the ELDO Project.

Cassini/Huygens Leaves the Earth

At 4:43 (EDT) on the morning of 15 October 1997, a Titan IV B, America's most powerful expendable booster, roared into the moonlit sky above Cape Canaveral carrying the international spacecraft Cassini/Huygens towards the Saturnian system, its final destination in 2004.

At 4:43 am EDT on 15 October, the Lockheed Martin-built USAF Titan rose quickly with a thunder almost equivalent to a shuttle, waking people up and down the space coast.

PETER GUALTIERI, WEST KENTUCKY NEWS

BY PETER D. MATA, FBIS
East Sussex, UK

THE FIRST ATTEMPT at a launch, on the 13th, was aborted after several problems were discovered during the countdown. First the launch tower refused to open, causing a 50 minute loss of time in the launch window. After this was solved, the Cassini control panels showed several red lights, that could have been either hardware or software related. Meanwhile the weather intervened with the winds in the upper atmosphere exceeding the safety limits. If there had been an accident, debris and toxic products would have blown ashore, rather than falling into the Atlantic.

The launch was postponed for 48 hours, giving time for the Cassini engineers at JPL, in Pasadena, to establish that the "red lights" were due to software problems. After much frantic work a software "patch" was made, tested and installed in the spacecraft. The final version of the on-board software will be uplinked during the seven year, 2.2 billion mile, cruise to Saturn.

The spacecraft will encounter Venus twice before returning to Earth and then pass on to Jupiter, gaining velocity at each planet on its way to Saturn. The circuitous path is required because even the mighty Titan/Centaur rocket was not powerful enough to send the biggest interplanetary probe yet launched, direct to its destination.

Protesters were out in force at the launch site, campaigning against the use of plutonium in the Radioisotope Thermoelectric Generators (RTGs) carried on Cassini to provide electrical power during the trip and for the four year long survey of Saturn and its rings and moons. Solar arrays would need to be 100 times bigger than those used in "near Earth" vehicles to provide the same amount of power. Although batteries are used in the European Huygens Titan probe, they only have to provide power for three to four hours during the descent to Titan's surface through the thick nitrogen and hydrocarbon atmosphere. ■

Cassini Spacecraft

Cassini is away on a 6.7 year journey for a four-year mission around Saturn.

After SOI (Saturn Orbital Insertion), Cassini will dispatch ESA's Huygens probe on a three week journey to Titan. There it will start a three hour mission (2° hours descent, ° hour on surface) relaying data to Cassini.

The 2°-storey Mariner-class spacecraft weighs 5650 kg and carries 3130 kg of fuel, 830 kg of which is needed to place Cassini in Saturn's grip during a 96 minute burn of one of two redundant engines. Last of the big probes, NASA's newest Discovery class missions will cost 10 to 15 per cent of Cassini's 3.4 billion dollar price tag.

What will project scientists be doing for the seven years of travel? "I'm going to be biting my fingernails", said Dr Carolyn Porco, Imaging Team leader, who expects up to a possible 500,000 images from Cassini and 500 to 1000 from Huygens. Detailed planning has yet to be done for all the Saturnian system flybys.

PETER GUALTIERI

ESA's Huygens Probe

Cassini carries ESA's Huygens probe as well as a high-gain antenna provided by ASI, the Italian Space Agency. In 2004 the Huygens probe will plunge into the thick atmosphere of Saturn's largest moon, Titan.

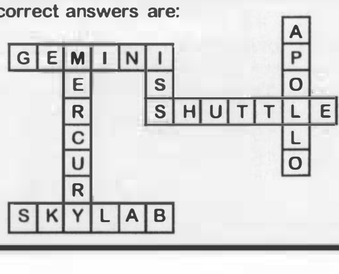
About 500 representatives of scientific, engineering and industrial teams from Europe, who have been involved in creating the Huygens Probe, were present at Cape Canaveral for the launch. The European Space Operations Centre (ESOC) at Darmstadt are monitoring the condition of the Huygens spacecraft and, on 23 October, confirmed that it was in excellent condition. The next major event will be the swingby at Venus on 21 April 1998.

'US Manned Space Programmes' Competition Winner

The winner to whom a book prize will shortly be dispatched is:

Captain B. Hall Warrington, UK

The correct answers are:



Landing STS-86

Excessive cloud cover on 5 October delayed the landing by one day.

STS-86 Commander Jim Wetherbee describes landing Atlantis. See below - "When You Land an Orbiter".

PETER GUALTIERI, WEST KENTUCKY NEWS

THE NEXT DAY crosswinds flirted with the 15 knot limit (12 knots at night) and then steadied, allowing a first revolution de-orbit and landing on KSC runway 15 on 6 October at 5:55 pm EDT. Winds were nine knots peaking to 14 knots.

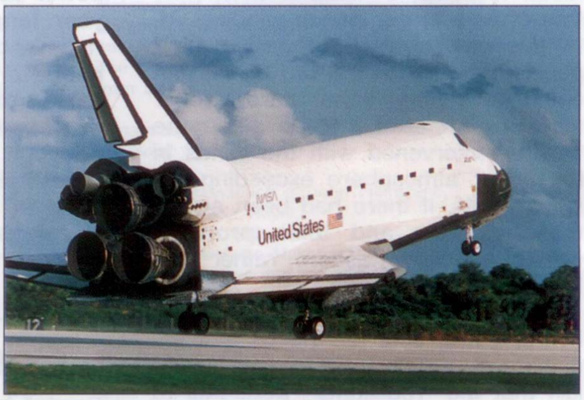
Because of the high crosswinds, dragchute deployment was delayed until de-rotation (nose wheel touch-down). This and commander Jim Wetherbee's late use of brakes (after dragchute was out) caused Atlantis to roll almost the entire runway length.

STS-86 entry flight director Linda Ham chose runway 15 for the advantage of having a slightly better sun angle. Though glare would not have been a problem at either end. Shuttle windshields puck up many pits and scratches which can obscure a pilot's view if illuminated in a certain way.

Ham also discussed the unprecedented launch attempt of an ELV (Expendable Launch Vehicle) nearly two hours prior to a shuttle landing. Lockheed Martin's launch window for Atlas 135 was set to close 15 minutes before STS-86 TIG (Time of Ignition) for de-orbit. This would allow 75 minutes for precautionary debris avoidance if the Atlas 2AS were destroyed up to four minutes into flight.

Although Echostar III launched on time at 5:01 pm on 5 October, Atlantis missed its 6:58 pm landing slot and also the next opportunity one and a half hours later and came down the next day on orbit 170 at 10 days 19 hours and 21 minutes total elapsed time.

A clear Florida day allowed viewers at the SLF (Shuttle Landing Facility) to see Atlantis well before entering the HAC (Heading Alignment Circle) and still supersonic. Following the 100 ton Atlantis around the HAC towards final approach clearly showed her tremendous sink rate.



Atlantis touches down on KSC Runway 15 in the late afternoon on 6 October 1997. NASA

Touching down right on the centreline, Atlantis raised the port landing gear - possibly due to the stiff crosswind - and bounced it back down. Each time a puff of smoke could be seen.

Also seen was the starboard gear trailing smoke all through rollout. Could this have been due to wind effecting weight distribution and/or shear on the beleaguered tyres?

Atlantis is due for scheduled orbiter maintenance downtime at Boeing's Palmdale facility in California. Its next flight is the third ISS assembly STS-92 in January 1999.

This was the 40th KSC shuttle landing and the 11th in a row in Florida.

PETER GUALTIERI, WEST KENTUCKY NEWS

After a late afternoon rain shower, the crew of STS-86 surround Mir veteran US astronaut Mike Foale. British born Foale, clutching son Ian, gives an exclusive interview to the BBC. Clockwise around Foale are Commander Jim Wetherbee, pilot Mike Bloomfield, Wendy Lawrence talking with Foale's daughter Jenna, Vladimir Titov, Scott Parazynski and Jean-Loup Chretien. The crew assembled on the apron of CCAWS Skid Strip runway on 7 October for their trip back to Houston nearly one day after returning from space.

PETER GUALTIERI, WEST KENTUCKY NEWS

When You Land an Orbiter

"You don't really care about the position relative to the centre line... What you really care [about] is the velocity... You don't want the vector to be diverging and getting farther away and approaching the side because there are alligators living in the moat.

"We have an interesting rudder system - it's relatively slow. It is huge... it sticks up into the airstream and you get some opposite effects. When you step on left rudder. [While on rollout] the vehicle will roll to the right because the rudder is way up above the centre of gravity of the vehicle... the centre of pressure is causing it to roll to the right."

JIM WETHERBEE

Forthcoming Space Shuttle Launches.

Mission	Target Date	Orbiter	Duration	Payload(s)	Incl
STS-87	19 November	Columbia	16 Days	USMP-4, Spartan-201-04	28.5
STS-89	15 January	Discovery	9 Days	Eight Mir Docking	51.6
STS-90	2 April	Columbia	16 Days	Neurolab	28.5
STS-91	28 May	Discovery	9 Days	Ninth Mir Docking	51.6
STS-88	9 July	Endeavour	10 Days	ISS-01	51.6

Ariane Launch Schedule.

No.	Date	Launcher	Satellites
100	23 September	42L	Intelsat 803
101	30 October	Ariane 502	Passenger Payloads
102	4 November	44L	Sirius 2 & Cakrawarta 1

The Revival of Mir

Late July to Early September 1997

- **On 5 August, Soyuz TM-26 was launched with the next Russian crew of Solovyov and Vinogradov.**
- **On 14 August, Vasily Tsibilyev and Alexander Lazutkin returned to Earth literally with a bump when the soft-landing retro-rockets failed to fire.**
- **On 18 August, the base block's central computer shut down and Mir lost attitude control.**
- **On 22 August, Solovyov and Vinogradov entered the Spektr module and reconnected the power cables from the module's solar arrays.**
- **On 6 September, Solovyov and Foale carried out a six-hour EVA, but found no visible breach in Spektr's pressure shell contrary to expectation.**

BY NEVILLE KIDGER
Leeds, UK

Introduction

The collision between the Progress M-34 cargo craft and the Mir complex on 25 June led to an emergency situation on the complex.

Mir Mission Report now continues with the recovery of the complex, picking up on the events reported at the end of the last Mir Mission Report in the October issue of *Spaceflight*, pp.350-354.

22 July
Status of the Mir Complex

At this time:

- The automatic attitude control was being provided by just eight gyrodynes.
- The batteries had been fully recharged.
- The Condensate Recovery System (CRS) had been reactivated following replacement of an air separation unit that developed a nozzle leak the previous week.
- The CRS was generating 2.5 litres of water a day for future use in the Elektron oxygen generator which remained powered down to conserve power.
- The Vozdukh carbon dioxide removal system was working.
- It was planned to provide oxygen for the following week from the tanks of the Progress cargo ship.
- The health of Commander Vasily Tsibliyev, who had suffered heart irregularities just days earlier, was no longer giving cause for alarm.
- Michael Foale had been cleared to help the two Russians perform "minor trouble shooting operations" on the complex as most of his science work had been lost in the depressurisation of the Spektr module and his role had to change from being just a researcher to actually performing operations with the Mir systems.

28 July
Greenhouse Experiments Continue

Foale reported that as part of the Greenhouse experiment, which was in the Kristall module, most of the Earth seeds and some of the space seeds had sprouted. NASA claimed this was the first time that a second generation of space plants had been grown.

On 23 July as part of the Greenhouse experiment, Foale had planted a new crop of the *Brassica Rapa* seeds grown aboard Mir in a continuing study of the effects of microgravity on a plant's life cycle.

Throughout the week, Foale continued his work on the Greenhouse experiment and on the colloidal gelation (CGEL) experiment studying the fundamental properties of colloids (small solid particles suspended in a fluid) in a microgravity environment.

30 July
Next Long-Stay Astronaut for Mir

NASA announced that Astronaut Wendy Lawrence had been replaced by her backup, Dr. David Wolf, for the next long duration stay on Mir. The change would enable Wolf to act as a backup crew member for spacewalks planned over the next several months to repair the damaged Spektr module. Lawrence on the other hand did not fit in the Orlan suit and never underwent spacewalk training. Lawrence was however still to fly on STS-86 in September, this being the flight that would deliver Wolf to Mir.

31 July
Next Cosmonaut Crew Pay-Rolled

Solovyov and Vinogradov flew to the Baikonur Cosmodrome to prepare for their 5 August launch to Mir. Their reserves Gennadi Padalka and Sergei Avdeyev also arrived at Baikonur on a separate plane. The crew selected for the mission would enter into a contract with the Energiya Corporation. ITAR-TASS said that the expected fee for each cosmonaut would amount to about US$40,000 made up of US$100 per day of the flight and about US$1,000 per EVA (six were expected during the EO-24 mission).

1 August
More Gyrodynes Activated

NASA said that 10 of the 12 gyrodynes were now working. (Over the weekend of 26/27 July, the crew had managed to repair one of the four nonfunctioning gyrodynes making nine operational.)

4 August 1997
Elektron Oxygen Generator Still Inactive

Tsibilyev and Lazutkin spent much time during the day working on the new Elektron unit, which had turned itself off when activated over the previous few days. A second, older unit in the Kvant-2 module had been powered off since late June when electricity to the module was limited because of the disconnection of solar array power cables from the damaged Spektr module.

Russian flight controllers continued to discuss methods to reactivate the Elektron once the new crew arrived on Mir.

NASA stressed that the shutdown of Elektron posed no problem or threat to crew safety or mission goals. Oxygen generating canisters were being burned periodically to provide ample oxygen for Mir. There was about a two month supply of the canisters on board, the agency said.

5 August
Next Cosmonaut Crew Launched

Solovyov and Vinogradov were launched in Soyuz TM-26 at 1536 GMT for a six-month stay on Mir. The spacecraft reportedly carried some 96.5 kg of extra equipment in place of French researcher Leopold Eyharts who had been scheduled to fly with the EO-24 crew. This equipment included tools for the EVAs and documentation as well as 40 kg of oxygen generating canisters.

7 August
Soyuz Successfully Docks

In preparation for the arrival of TM-26, the Progress M-35 cargo spacecraft,

which had been attached to the rear Kvant docking port, had been undocked at 1146 GMT the previous day into a station-keeping orbit at a safe distance from the complex.

Solovyev guided Soyuz TM-26 to a manually performed docking at 1702 GMT. In the latter stages of the approach, the Soyuz's Kurs automated guidance system had lined up the approaching craft so precisely that at a distance of about 10 m Solovyov's view of a visual target (a cross) on Mir was actually obscured. The veteran cosmonaut disconnected the Kurs unit, backed Soyuz some 2-3 m away from the complex and brought the craft in for a flawless manual docking.

After docking, the new cosmonaut crew performed leak checks between the Soyuz capsule and Mir. Hatches between the two vehicles were opened at 1832 GMT.

13 August
Watching the Drinking Water Supply

NASA reported that available drinking water was the item in most limited supply. Taking into consideration the current on-board supply and anticipated production and consumption rates, the supply could be expected to last into the October/November timeframe by which time two different vehicles, the space shuttle and a Russian Progress, were scheduled to arrive with additional supplies.

14 August
Cosmonauts Return to Earth With a Bump

The EO-23 crew of Vasily Tsibliyev and Alexander Lazutkin successfully returned to Earth, piloting the Soyuz TM-25 descent cabin to a landing at 1217 GMT some 168 km south-east of the city of Dzezkazgan in Kazakhstan to end their 185 days in space.

The two cosmonauts' misfortunes continued to the end of their mission when the soft-landing engine of the descent cabin failed to fire causing a harder landing than normal. Tsibiliyev said later that had the third seat been occupied the cosmonaut seated there would have been injured by the impact.

By the end of the day it was reported that the Elektron oxygen-generation system in the Kvant module was performing normally again, thanks to the flushing of a hydrogen vent line in the system, which removed a small clump of alkaline residue.

15 August
Soyuz Used to Inspect Mir

The crew climbed into the Soyuz TM-26 craft and undocked from the rear Kvant port at 1330 GMT and flew around the complex for 44 minutes.

The manoeuvre allowed Solovyev to fly Soyuz around Mir rather than have flight controllers rotate Mir through 180 degrees to present the docking port to the Soyuz. This approach ensured that Foale would have the best possible lighting conditions for a video survey of the damaged Spektr module.

Solovyev backed the Soyuz away from Mir to a distance of about 50 m. Then, the complex was manoeuvred to an orientation to illuminate Spektr for the video survey. The video was downlinked three days later to assist controllers in planning an external spacewalk early next month.

At 14:14 GMT Solovyev manually redocked the craft at the forward docking port.

18 August
Computer Shuts Down and Attitude Control is Lost

Progress M-35 was redocked to Mir at 12:53 GMT and was to remain docked to Kvant to continue as a collection point for the storage of rubbish until it was jettisoned before the arrival of the next Progress in early October.

During the docking procedure however the base block's central computer shut down and Mir lost attitude control.

Solovyev used the TORU system to manually guide the Progress to a smooth linkup with Mir's rear Kvant docking port after Chief Russian Flight Director Vladimir Solovyev directed him to switch from the KURS automatic system.

Solovyev said the loss of the computer would delay the planned internal spacewalk by the EO-24 crew to reconnect power cables in the depressurised Spektr module by two or three days to allow flight controllers time to restore attitude control to the Mir.

The jets on Soyuz were fired periodically to orient the complex to the Sun for battery charging and less than three hours after the loss of the central computer, Mir was once again stable and properly oriented. Once the batteries were fully charged, the central computer could be reactivated and the station's orientation to the Sun maintained by Mir's primary reaction control jets.

The gyrodynes would then be spun up to provide the primary means of orienting the complex (the gyrodynes were spun down after Mir lost its pointing capability).

The Elektron oxygen generator, now working normally, was shut down before the Progress redocking to conserve power.

19 August
Computer Fault Rectified

The computer failure was quickly traced to a faulty data processing box. The cosmonauts swapped the unit and reinitialised the computer to resume automatic attitude control.

Mir's jets once again maintained attitude control and by next morning the gyrodynes were spun up and other Mir systems were back on line, including the Elektron unit.

22 August
Inside Spektr

Solovyev and Vinogradov conducted the long-planned internal spacewalk inside the depressurised Spektr module, reconnecting 11 power cables from the Spektr's solar arrays to a new custom-made hatch (the so-called "hermaplate") which actually had 23 connectors with some unused on this repair.

The cosmonauts worked in the darkened multiple docking unit where the four science modules and Soyuz were docked. Foale was inside the Soyuz descent cabin using radio to communicate with his two colleagues.

Before the two men could begin their work there were two problems. First an air leak was detected when a hatch was not sealed properly and then (what was termed "serious" by one of the cosmonauts) Vinogradov's left hand glove exhibited a leak, requiring the docking unit to be repressurised and the glove exchanged.

The hatch to Spektr was opened by Vinogradov at approximately 1110 GMT with Mir out of communications range of Russian flight controllers. He floated into the darkened module feet first to begin the job of connecting the power cables to the special hatch plate. Solovyev joined Vinogradov in Spektr later, helping him inspect several areas behind panels where Russian engineers believed leak points could have been present as a result of the collision with Progress M-34. No obvious signs of damage to the module were reported.

Vinogradov described the Spektr as being in generally good shape, with a few "white crystals" floating around, possibly from soap or shampoo and a thin layer of frost on experiment counters, which had been exposed to the vacuum of space for the previous two months.

In addition to the repair work, the cosmonauts also retrieved a vacuum cleaner, Michael Foale's personal effects and several other unspecified items from inside Spektr and took documentary video of the new electrical connections and the interior of the module.

Solovyev and Vinogradov finally left Spektr, closing the hatch at 1430 GMT to officially end the spacewalk, after the hatch had been left open for three hours and 16 minutes.

Foale, speaking in English, congratulated the spacewalkers and ground support personnel saying, "We did everything we set out to do and more. Well done, everybody."

25 August
Power Flows from Spektr

Ground controllers acknowledged that an additional 40 amps of electricity were flowing into the Kvant-2 module following the hookup of an adapter cable to route newly found power from Spektr through the Kristall module into Kvant-2. But commands sent to the solar arrays, to try to slew or move them into a better orientation to face the Sun, were not successful. NASA said that one of the 11 power cables mated to the hermaplate was designed to re-establish the pointing capability of the arrays.

By the next day 90 amps of electricity were flowing into the Kristall module and on 27 August Foale told Russian ground controllers, "Kristall has power, the fans are running". The plan was to first power up the Kvant-2 module, then Kristall and finally Priroda after the external inspection of the Spektr module.

28 August
Kristall Up and Running

Lights were turned on in the Kristall and Kvant-2 modules. In a brief status report from orbit, Foale said that Kristall was actually humming and running with running fans, running pumps and that the temperature there was about 23°C. Foale was working in Kristall with the Greenhouse experiment.

29 August
More Power from Spektr Arrays

TsUP reported that the restoration of electrical power from the Spektr module's solar arrays had resulted in up to 47 amps of electricity for the Kvant-2 module and up to 100 amps of power for Kristall. Work was being conducted to try to establish a way of restoring the pointing control of the Spektr solar arrays.

31 August
Birthday in Orbit

Vinogradov celebrated his forty-fourth birthday with a videoconference greeting from his family at TsUP.

4 September
Spacewalk for Foale Approved

US and Russian managers jointly agreed to proceed with a planned six-and-a-half-hour EVA on 6 September by Solovyov and Foale.

The decision to press ahead with the EVA came at the conclusion of a joint readiness review chaired by NASA Shuttle-Mir Program Director Frank Culbertson and his Russian counterpart, Valery Ryumin, RSC Energia Mir-Shuttle Director.

Final approval to enable Foale to become the second US astronaut to participate in a US-Russian spacewalk outside Mir was jointly decided after a detailed review of Foale's on-orbit training, safety criteria, and the procedures and plans for the EVA.

An additional task added to the survey of the Spektr module was the manual reorientation of one of the solar panels on the module.

6 September
External Inspection Fails to Find A Spektr Rupture

Michael Foale (left) with Commander Vasily Tsibilyev. NASA

Anatoli Solovyev and Michael Foale conducted a six-hour EVA to inspect the damage to the Spektr module. Although Solovyov conducted a thorough analysis of the damage to one of Spektr's radiators and its damaged solar array, he reported no visible signs of a hole in the module's hull.

Chief Flight Director Vladimir Solovyev said "we had the crew look at seven of the most seriously damaged areas of the Spektr module but nothing suspicious could be found that could be named as causing the breach in the Spektr module."

During the first stage of the EVA Foale manoeuvred Solovyev, riding the Strela telescopic crane into position at the Spektr module, where the Russian performed a visual inspection of the damaged areas around the radiator which had been crumpled by the Progress collision. Solovyev used a cutting tool to remove thermal insulation covering the struts and support beams of the damaged radiator to try to locate areas where a breach in the Spektr's pressure shell might be evident. Solovyev reported that he found bent and broken struts but no puncture. Since there was no visible breach in the hull, Russian flight controllers determined that there was no need to install handrails at that site for future repair work.

Next, Foale and Solovyev moved to the damaged solar array to inspect that site. Based on the visual inspection, Solovyev indicated that some distortion now existed at the base of the array, which was canted to one side.

Flight Director Solovyev said later that the base of the solar array could be a suspect for leakage as a result of the Progress collision. Video of the damaged solar array base taken by Solovyev was expected to offer Russian analysts an opportunity for further study of its condition. The crew stored handrails in the vicinity of the damaged array for possible use on a future EVA.

Solovyev and Foale then moved on to two of Spektr's undamaged solar arrays, where Solovyev used an extendible pole with a hook on the end to slowly pull the Spektr's fan tail solar array to a new orientation to increase its ability to collect solar energy. The commander then slowly pushed the main array opposite the damaged array to improve its orientation.

Foale was able to retrieve a US radiation detection monitor just before reentering the airlock. The Benton dosimeter had been left by Foale's predecessor, Jerry Linenger, during a spacewalk on 29 April.

Solovyev and Foale began their spacewalk at 0107 GMT after Foale opened the hatch to the Mir's Kvant-2 airlock. The hatch was sealed at 0707 GMT.

After removing his spacesuit, Foale radioed down to Russian mission controllers, "I'm really honoured to take part in this spacewalk and I thank everyone for helping me to prepare for it."

It was Solovyev's 11th spacewalk in five expeditions to Mir and the second spacewalk for Foale, who became the first person to conduct a spacewalk in both a US and a Russian suit. ■

Voyager Missions

20 Years in Space and Counting

Twenty years after launch and long after completing their spectacular planetary flybys, NASA's twin Voyager spacecraft are billions of miles away and still sending data to Earth. The two spacecraft are now moving toward another milestone - crossing the heliopause - the invisible boundary separating the Solar System from interstellar space.

Voyager 2 was launched on 20 August 1977 and Voyager 1 was launched on 5 September 1977.

Voyager 1 encountered Jupiter on 5 March 1979 and Saturn on 12 November 1980. Then its path was bent northward by Saturn's gravity which sent the spacecraft out of the ecliptic plane (close to which all the planets except Pluto orbit the Sun).

Voyager 2 arrived at Jupiter on 9 July 1979 and Saturn on 25 August 1981. It was then sent on to Uranus on 25 January 1986 and Neptune on 25 August 1989. Neptune's gravity then sent it out of the ecliptic plane toward interstellar space.

By 26 September 1997, Voyager 1 was 4.9 billion km from Earth and had travelled 12.0 billion km since launch. It was departing the Solar System at 17.4 km/s. Voyager 2 was 7.9 billion km from Earth and had travelled 11.3 billion km since launch. It was travelling at 15.9 km/s.

Both spacecraft have enough electrical power and attitude control propellant to continue operating until about 2020 when there will not be enough electrical power for the science instruments to operate.

The Voyagers are now so far away that it takes 9 hours for a radio signal travelling at the speed of light to reach the spacecraft. Science data are returned to Earth in real-time to the Deep Space Network antennas located in California, Australia and Spain. Voyager 1 will pass the Pioneer 10 spacecraft in January 1998 to become the most distant human-made object in the Solar System.

Since 1989 when Voyager 2 encountered Neptune, both spacecraft have been studying the space environment in the outer Solar System. Science instruments on both craft have been sending signals that may be coming from the heliopause.

Before the spacecraft reach the heliopause, they will pass through a termination shock - the place where the solar wind abruptly slows down from supersonic to subsonic speed. Reaching the termination shock and heliopause will be major milestones, and the Voyagers will be the first spacecraft to have travelled there and to discover exactly where they are.

Data Playback From Galileo

During October Galileo continued to return data mainly from its previous encounter with the moon Callisto. By mid-October it was half-way between encounters (i.e. at its farthest point from Jupiter for the current orbit) before travelling back toward the Jupiter system.

ALTHOUGH Callisto continued to be top of the spacecraft to-do list, a switch was made during the week of 20-26 October to playback data from Jupiter's north and south polar regions and observations designed to search for lightning discharges on the nightside of Jupiter. Observations of Io and Europa taken a few week previously when the spacecraft was blocked from the Sun by Jupiter were then scheduled to be returned.

The instruments involved are the Near Infrared Mapping Spectrometer (NIMS), the Ultraviolet Spectrometer (UVS) and the Solid State Imaging (SSI) camera.

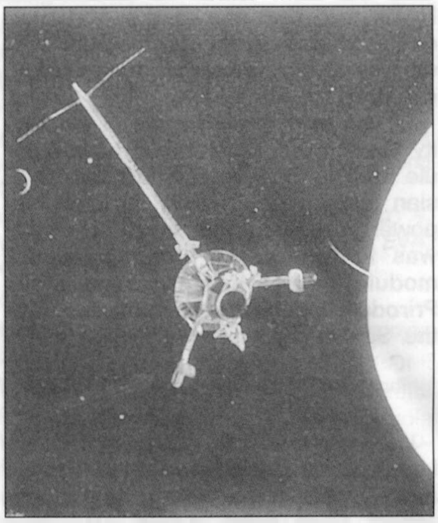
Despite the loss of the Galileo's main telecommunications antenna, several imaginative engineering solutions enabled the Galileo Project team to carry out its mission, the introduction of routine arraying of the Deep Space Network antennas represented the final instalment of the steps taken.

As the Earth turns relative to Galileo's position in the sky, different arrayed antennas hand-off the receipt of data from Galileo over a 12-hour period. The array electronically links the stadium-size, 230-foot diameter dish antenna at the Deep Space Network complex in Goldstone, CA, with an identical antenna located at the Australia site, in addition to two 112-foot antennas at the Canberra complex. The California and Australia sites concurrently pick up communications from Galileo. The Parkes radio telescope joins in with the Canberra station for six hours each day.

Arraying, together with other improvements in the space-to-ground communications link, increases by 10 times the quantity of raw data received from Galileo. Changes in the way the Galileo spacecraft edits and compresses data, results in an additional factor of 10. When taken together, these improvements enable Galileo to meet 70 per cent of its original science goals.

Software changes on the spacecraft now ensure that every bit of science and engineering telemetry from the spacecraft carries as much information as possible. So while the data amount received from Galileo is comparatively small, all of it is highly valued.

Galileo's high-gain antenna was to have provided a 134-kilobit/s real-time data rate from Jupiter. Had no im-



Galileo at Jupiter. NASA/JPL

provements been made in the Deep Space Network, only a 10-bit/s data rate would have been possible with Galileo's small low-gain antenna for most of the mission. These improvements, however, along with the changes made on the spacecraft, further increased the downlinked data to an effective rate of 1,000 bits/s.

Towards mid-October, Galileo adjusted its playback schedule after some breaks when the Deep Space network antenna time was needed for Mars Pathfinder and Mars Global Surveyor. These pauses led to the loss of playback time from the recent Callisto encounter. Some of the Callisto data where subsequently transmitted and the playback schedule in late October was varied to include observations of Jupiter and the moons Io, Europa and Amalthea. Playback interruptions also arise during orbit trim manoeuvres and for regular maintenance of the spacecraft's tape recorder. Since June 1996, JPL has been releasing new Galileo images daily, five days a week. These are available on the Galileo home page at: http://www.jpl.nasa.gov/galileo.

Galileo at Europa

Galileo's next Europa encounter is on 16 December 1997 and is notable for its closest-approach of just 200 km marking the closest flyby of any celestial body. Subsequent encounters for 1998 are on 10 February (3562 km); 29 March (1649 km); 31 May (2521 km); 21 July (1837 km); 26 September (3598 km); and 22 November (2281 km).

Mars Global Surveyor

Aerobraking Phase Discovers Magnetic Field: Unexpected Data May Unravel Early History

The Surveyor spacecraft began orbiting Mars on September 11 after its main rocket engine that fired for 22 minutes expending 280 kg of propellant to slow its velocity by 973 m/sec. (*Spaceflight*, November, 1997, p.362). The resulting capture orbit was highly elliptical with a high point at an altitude close to 54,000 km and a low point at only 263 km above the Martian surface.

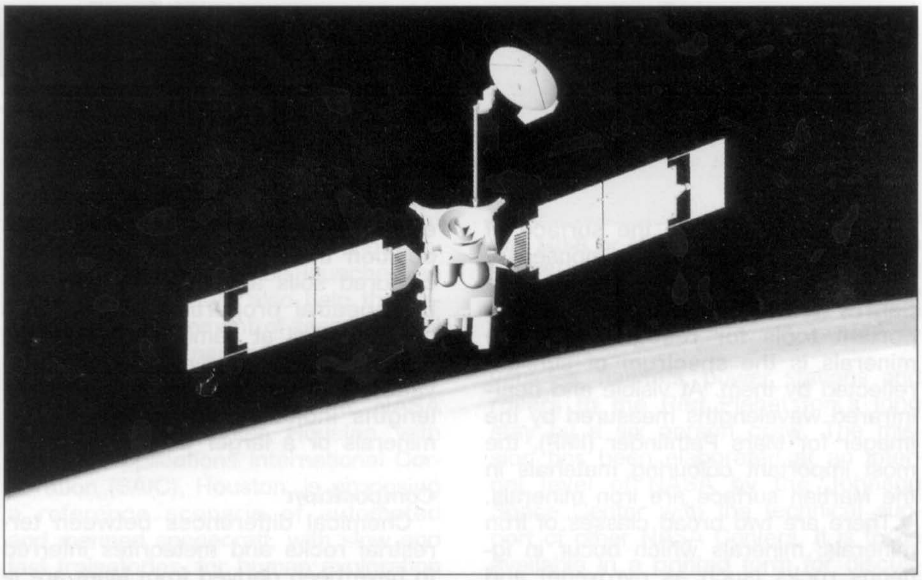
BY RICHARD L.S. TAYLOR
London

QUITE OFTEN major scientific discoveries - ones that may completely overturn our previous ideas or misconceptions - result from a procedure that was adopted for quite different reasons. An event of this kind has occurred with the Mars Global Surveyor (MGS) which, in order to save fuel, is using the technique of aerobraking to slow it down into a circular orbit.

The first 'step down' into the upper atmosphere came on 16 September. Surveyor's main engine was then fired for 6.5 s when the spacecraft was at the highest point of its orbit reducing its velocity by 4.4 m/s. This manoeuvre lowered the spacecraft to 150 km above the surface of the planet where air resistance on its solar panels has since slowed the spacecraft by an average of 1 m/s on each orbit. By 27 September, the resulting deceleration had already lowered the highest point of the orbit to 1690 km and over the following four months this will drop further to about 450 km.

Mars Global Surveyor's magnetometer discovered the outermost boundary (the so-called bow shock) of the planet's magnetic field during the in-bound leg of its second orbit and again on the outbound leg. These initial observations suggested a field with a polarity similar to that of the Earth's and a maximum strength not exceeding 1/800th of that at the Earth's surface.

However this picture of Mars soon gave way to a more interesting and complex one. What has emerged from the close encounters so far is that Mars is a world covered with magnetic anomalies. These differ significantly in strength and direction of magnetisation. The MGS team report that there are at least eight or nine patches of magnetisation, each a few hundred kilometres in size. The greatest field strength measured so far by the MGS magnetometer is 400 nT (nanoteslas) about 1/75 of the Earth's global field at a corresponding altitude. Considered as a magnetic anomaly this Martian field is significantly larger than that of any similar anomaly measured by satellites for the Earth or Moon because, according to David Stevenson of CalTech, Martian magma appears to be enriched in magnetite, a mineral that can readily capture and retain an impressed magnetic field.



An illustrative view of Surveyor in relation to Mars. NASA/JPL

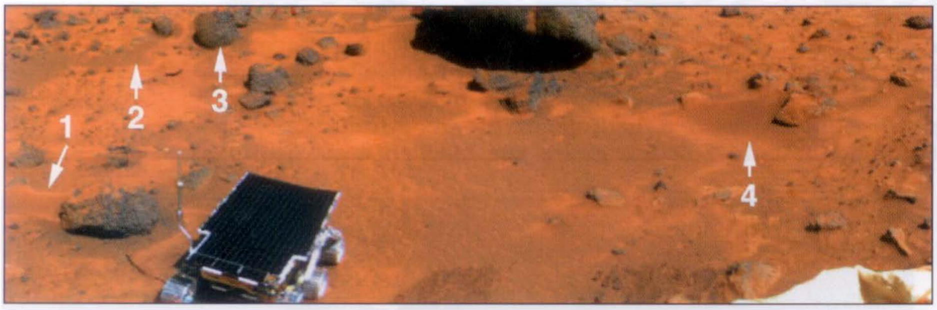
This emerging picture of Mars suggests that currently the Martian interior must be dynamically inactive, and hence magnetically dead - so that there is currently no active Earth-like dynamo. Mars appears to have once had a strong global field, but the field is no longer present. According to magnetometer team member John Connerney of Goddard Space Flight Center the remnant fields detected by MGS resemble giant bar magnets embedded in the outer crust of Mars. These localised remnant fields seem to have frozen into regions of the crust where magma was solidifying perhaps in some cases billions of years ago. This process of freezing in the ambient magnetic field intensity and directionality occurs widely on Earth, indeed it is the chief indicator that seafloor spreading - plate tectonics - is taking place. The magnetic banding on each side of the mid-oceanic ridges records the changes in the polarity of the global magnetic field. Regions of terrestrial flood basalts can be dated also at least in part by the determination of the polarity of their remnant magnetisation which was set as their material cooled below the Curie point as they solidified. The variation in the directionality of the magnetisation of the Martian magnetic anomalies suggests that its magnetic field was also subject to rapid and random periods of inversion of polarity.

Given these newly discovered records of the past behaviour of the global magnetic field of Mars it should be possible to establish a chronological relationship between the ancient magnetic field and the present geological features on the planet's surface and to establish a time scale for the transition from a highly active Mars to the present state of senescence. A great deal of work will have to be done before such a history of Mars can be written, but given the great steps forward already made by Pathfinder and Global Surveyor, and the whole succession of Mars probes to come over the next few years, we could be on our way to building a comprehensive understanding of the most Earth-like of all the other planets in the Solar System.

The planet Mars has always fascinated mankind, and it seems certain that it will fascinate and surprise us even more in the immediate future. The next few years are likely to see an era of planetary exploration more exciting than anything we could have imagined 40 years ago when Sputnik 1 first extended the reach of human science and technology beyond the confines of the Earth. ■

Pathfinder Results

For 12 weeks following its successful landing on Mars on 4 July, the lander and rover studied soil and rocks in the close vicinity of the landing site, discovering a diversity of properties.

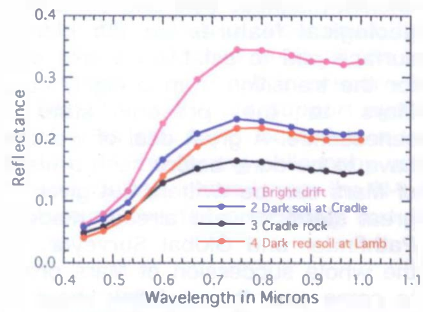


The rover is seen in the vicinity of the lander. A part of the lander's airbags appears at the lower right. The numbers refer to the graph below. NASA/JPL

Reflectance

Rocks and soils on the surface of Mars are thought to be composed of minerals similar to those found on the Earth's surface. One of the most important tools for recognising these minerals is the spectrum of sunlight reflected by them. At visible and near-infrared wavelengths measured by the Imager for Mars Pathfinder (IMP), the most important colouring materials in the Martian surface are iron minerals.

There are two broad classes of iron minerals: minerals which occur in igneous rocks (such as pyroxene) and have a relatively flat spectrum with low reflectance and ferric iron minerals, which occur as weathering products, reflect longer-wavelength light and absorb short-wavelength light, and hence are very red in colour. The relative brightnesses of Martian surface materials in IMP's different wavelength filter is therefore a powerful tool for recognising the iron minerals present.



Data from the IMP (Imager for Mars Pathfinder). NASA/JPL

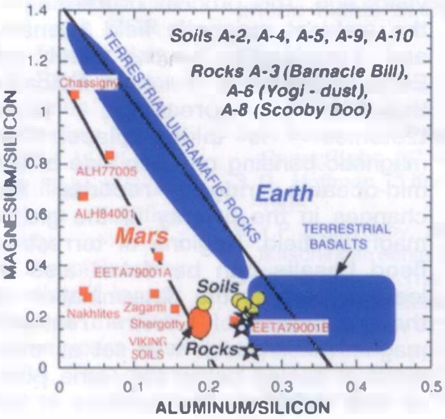
The surface near the rover's egress from the lander contains mainly bright red drift (#1), dark gray rocks such as Cradle (#3), soil intermediate in colour to the rocks and drift (#2), and dark red soil on and around the rock Lamb (#4). Globally, Mars is characterised by similar colour variations. The spectra, measured using the full 13-colour capability of IMP, provide evidence for the mineralogy of the unweathered rocks and highly weathered red soils.

Rocks are less red and have less of a bend in the spectrum at visible wavelengths, indicating less ferric minerals and a more unweathered composition than drift. The intermediate coloured soils appear intermediate in the spectral properties as well. The dark red soil at Lamb is darker than drift but about equally as red; the curvature of a spectrum at visible wavelengths indicates either more ferric minerals or a larger particle size.

Composition

Chemical differences between terrestrial rocks and meteorites inferred to have been derived from Mars are illustrated in the diagram below on the basis of preliminary X-ray data. The Martian meteorites (as well as Viking soil analyses) all plot to the left of the fields for Earth rocks. Pathfinder APXS (Alpha Proton X-ray Spectrometer) analyses of rocks (stars) and soils (dots) appear to plot in the gap between these previously defined fields, although they are similar to at least one basaltic meteorite. Two of the stars represent the compositions of Barnacle Bill and Yogi. The analysis of Yogi appears to be contaminated by dust adhering to the rock's surface. The rock composition can be estimated by subtracting a portion of dust; the resulting Yogi composition is very similar to that of Barnacle Bill. Barnacle Bill is also contaminated by dust, but to a lesser extent.

Rock and soil compositions compared. NASA/JPL



Pathfinder's Extended Mission

By the end of September the rover had been operating 10 times longer than its primary mission design of seven days, while the lander had been operating 2.5 times longer than expected.

The rover then completed its last alpha proton X-ray spectrometer study for a while on taking compositional measurements of a rock nicknamed Chimp, located just behind and to the left of an area called the "Rock Garden".

Follow-on plans called for Sojourner to begin a 50 m clockwise stroll around the lander to perform a series of technology experiments and hazard avoidance exercises and then be driven back to a magnetic target on the ramp of the lander. Meanwhile, the Pathfinder lander camera would continue to image the Martian landscape in full-resolution colour as part of its goal to provide a "super panorama" image of the Ares Vallis landing site. Each frame of this panorama is imaged using 12 colour filters plus stereo.

This image mosaic shows areas traversed by the Sojourner rover. The large, prominent rocks on the right comprise the "Rock Garden". The three main rocks making up this assemblage were all analysed by Sojourner's Alpha Proton X-ray Spectrometer (APXS). They are (from left to right) "Shark", "Half Dome" and "Moe". Other rocks examined by the APXS include "Wedge" (wedge-shaped rock in middle foreground), "Stimpy" (in front of Moe), and "Chimp" (tabular rock in middle-left background). NASA/JPL

Both lander and rover are solar-powered and carry batteries to conduct night-time science experiments and keep the lander warm during the sub-freezing nights on Mars. Normal usage has already fully depleted the rover's non-rechargeable batteries, limiting it to daylight activities only. The lander battery, which packed more than 40 amp-hours of energy on landing day, performed perfectly during the 30-day primary mission, but was down to less than 30 per cent of its original capacity.

At the end of September, difficulties were experienced in communicating with the lander. On 7 October, communications were re-established after four days of silence. No data were received, but the receipt of a signal indicated that the lander was operational. Meanwhile the rover, which is programmed to return to the lander and begin circling it when it has not heard from the lander for five days, started that activity on 6 October.

By 16 October no further signal had been received from the lander since that of 7 October. Daily uplinks to it were being continued.

A Decade of Missions to Mars

The success of Mars Pathfinder with the Sojourner rover marks the brilliant beginning of "faster, better, cheaper" missions for the exploration of the Solar System. It is the second spacecraft in NASA's Discovery programme of low-cost spacecraft with highly focused science goals; the first one is the NEAR probe en route to study asteroids.

BY THEO PIRARD
Belgium

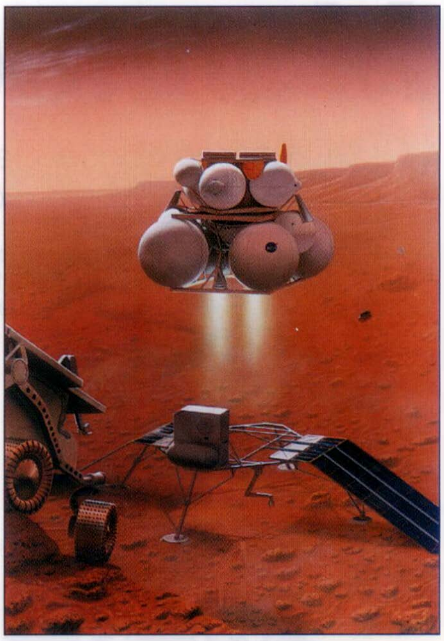
The Mars Pathfinder mission, along with Mars Global Surveyor, mark the beginning of a new era in Mars exploration and an ambitious new US initiative to send pairs of spacecraft to the Red Planet every 26 months in a sustained programme of robotic exploration extending well into the next century.

This programme of robotic exploration will expand scientific knowledge of Mars in three important area of investigation:

- To search for evidence of past life on Mars, after the evidence - revealed by scientists of NASA Johnson Space Center - from the meteorite found in Antarctica that primitive life may have existed there more than 3.6 billion years ago;
- To understand Martian climate in order to understand the past and future of the Earth's climate better;
- To survey Martian geology and resources that could be used to support future human missions to Mars.

This $1 billion programme combining low-cost probes of the Discovery and New Millennium initiatives of NASA is to culminate in a robotic sample return mission to be launched as early as 2005. It will also help the design and development of technological capabilities for manned expeditions to Mars.

The Exploration Office at NASA Johnson Space Center, Houston, with Science Applications International Corporation (SAIC), Houston, is proposing a reference scenario of automated and manned spacecraft, with slow and fast trajectories, for human exploration of Mars. This first scenario is based upon a minimum of four launches of vehicles, habitats, power stations and rovers to the Red Planet for a long stay by a six person crew. The mission has been elaborated at an internal level of NASA by the Johnson Space Center with the technical support of other NASA Centers. It is to be available in a printed form for discussion at federal and international levels. See overleaf for details. ■



The MISR or Mars ISRU (In-Situ Resources Utilisation) Sample Return will use propellant produced from the Martian atmosphere to send a capsule back to Earth in 2007-2008. NASA/JSC

NASA Spacecraft Missions to the Red Planet.

Mission dates: launch/arrival	Mission Name (prime contractor)	Description and main characteristics of the mission	NASA cost (1997 value)
4 December 1996/ 4 July 1997	Mars Pathfinder/ Carl Sagan Memorial Station + Rover (NASA JPL)	Discovery mission to demonstrate low-cost entry and landing system, rover mobility; in-situ study of Mars surface and weather.	$171 million + $25 million for the rover.
7 November 1996/ 12 September 1997	Mars Global Surveyor (Lockheed Martin)	Global reconnaissance of physical and mineralogical surface characteristics, water resources, geological structures.	$148 million.
10 December 1998/ Late 1999	Mars Surveyor '98 Orbiter (Lockheed Martin)	Study of changes in the Martian atmosphere, definition of atmospheric water content; primary communications relay.	Total cost for the Martian probes of 1998: $187 million.
3 January 1999/ Late 1999	Mars Surveyor '98 Lander + 2 Microprobes (Lockheed Martin)	In-situ analysis of surface chemistry, topology and mineralogy, continuation of weather studies, detection of water in the ground.	+ $26 million for the New Millennium microprobes.
February 2001/ Late 2001	Mars Surveyor '01 Orbiter (Lockheed Martin?)	Global remote sensing studies of mineralogy and chemistry in the surface of Mars, identification of water reservoirs.	Total cost for the Martian probes of 2001: $250 million. (Development)
March 2001/ Late 2001	Mars Surveyor '01 Lander + Rover (Lockheed Martin?)	Soil, dust and radiation measurements over tens of km at site selected from Mars Surveyor Orbiters of 1997 and of 1999; tests of in-situ propellant production plant.	
March 2003/ Late 2003	Mars Surveyor '03 Orbiter (NA)	Continuation of Mars Surveyor '01; communication and navigation relay for landers and rovers.	Total cost of combined missions of 2003: $220 million. (Development)
March 2003/ Late 2003	Mars Surveyor '03 Lander + Rover (NA)	Selection and collection of samples for in-situ analysis and for Mars sample return mission of 2005.	
Late 2004/1st half 2007 [1st half 2008 for Earth return]	Mars Sample Return Mission	Return of samples from one of the two rovers launched in 2001 and 2003.	Estimated cost: $400 million. (Development)

Manned Mars Missions

NASA Johnson Space Center Proposes a Reference Plan for Manned Missions on Mars Which Could Start in 2007 (50th Anniversary of Sputnik)

The reference scenario of NASA aims to establish a fully autonomous long-time outpost on Mars before the arrival of manned spacecraft. Such a scenario reflects that of the Great Explorers who travelled for many months and years around the world stopping near a river or at an island, where they would establish outposts with consumables for the follow-on expeditions.

BY THEO PIRARD
Belgium

Introduction

Before sending a six-man crew to work for 500 days at the surface of the Red Planet, NASA is envisioning a step-by-step approach to achieve a permanent presence with standardised systems in place within a time interval of two years. The techniques involve:

- The launch of a minimum of three automated cargo vehicles to Mars;
- The use of aerobraking manoeuvres for orbit and for descent;
- Surface rendezvous operations; and
- The establishment of an autonomous outpost with nuclear power supply and with in-situ resources utilisation.

For their return to Mother Earth, the Martian walkers/workers will rendezvous with a transit habitat in Mars orbit and come back with a direct entry at Earth. They will use a pressurised module or ERV (Earth Return Vehicle) for departure from the Mars system, an Apollo-type capsule or ECCV (Earth Crew Capture Vehicle) for re-entry into the Earth's atmosphere and recovery at the surface (on a steerable parafoil).

The challenging technologies to be evaluated for selection in the framework of an international programme for human exploration of Mars call for the use of common, standardised systems for low-cost development and on-line production.

A Heavy Launch Vehicle to Launch up to 240 tons in LEO

NASA in the reference mission considers rocket systems from the USA and from Russian and Ukraine. The first stage of the launcher could be a modified Energia core with Zenit boosters, a new core stage based on the Shuttle Space Transportation System with liquid boosters, or a new vehicle using technology derived from the Saturn V. The upper stage would use a single Space Shuttle Main Engine. Solutions with European, Japanese, Chinese rockets are not rejected.

Advanced Rocket Engines with Nuclear Reactor for the Trans-Mars Injection Stage

NASA proposes upper stages with three (for cargo vehicles) and four (for manned missions) ND (NERVA Derivative - Nuclear Engine for Rocket Vehicle Application) engines to send on a single launch from Earth orbit up to 100 tons to Mars orbit or some 65 tons to the Mars surface. NASA envisions American (Rocketdyne, Westinghouse, Pratt & Whitney, Aerojet, Babcock and Wilcox) and Russian (Energopool) technologies in reactor systems to achieve specific impulse of 900 seconds and more.

The Aerocapture System

A single family of biconic aeroshells would be used to perform the Mars orbit capture manoeuvres and the Mars entry phase for descent to the surface. The proposed aeroshells would have mass of some 17 tons and overall lengths between 15 m (for the MAV to land) and 19 m (for the ERV to orbit).

Habitats

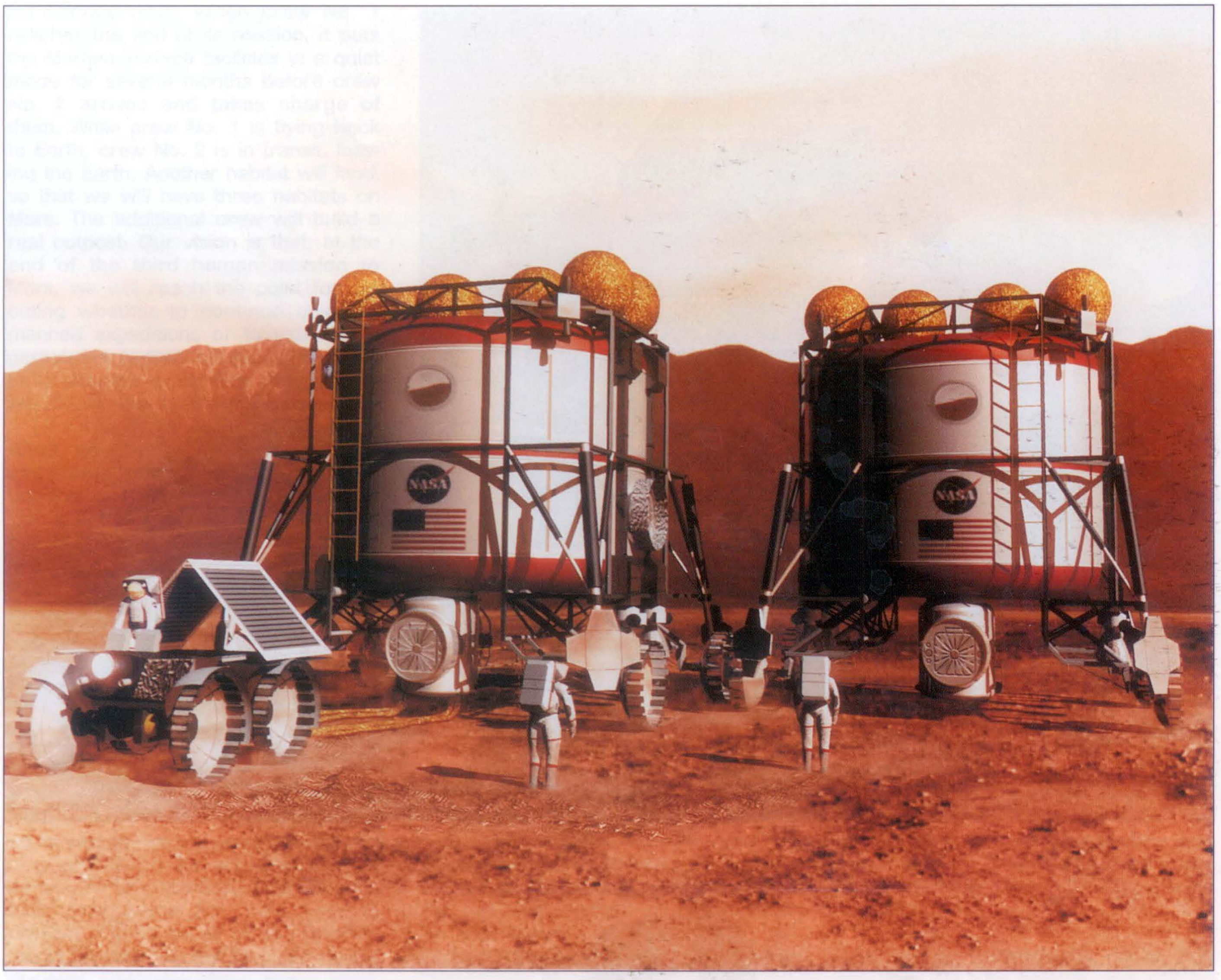
The same type of habitats would be robotically deployed in Mars orbit or at the surface. Their common concept with long-time life support systems to be tested first as a module of the International Space Station. Each habitation element would consist of a struc-

Typical Scenario for Manned Operations on Mars.*

Mission dates: launch/arrival	Mission Objectives	Description of challenges and operations
September 2007/ [return to Earth: October 2011]	Unmanned ERV-1 in Mars orbit, with transit habitat and fuelled TEI stage.	Launch with heavy rocket in Earth orbit and with NTR to achieve minimum energy direct trajectory to Mars; orbit capture with aerobrake manoeuvre.
September 2007/ August 2008	Unfuelled MAV-1 (empty ascent stage) on Mars surface + propellant production module + nuclear power plant (160 kW) + utility truck + rover.	Use of heavy rocket and NTR to reach Mars on minimum energy trajectory; aerocapture before descent manoeuvre; autonomous deployment of the nuclear reactor (1 km from the ascent vehicle) and of the propellant production plant.
October 2007/ September 2008	Habitat 1 on Mars surface + nuclear power plant + utility truck + teleoperable science rover.	Heavy rocket and NTR using minimum energy trajectory to deliver a second lander to the Mars surface; creation, close to the MAV-1 site, of a surface outpost with pressurised laboratory and second, backup nuclear power plant.
October 2009/ August 2010	Unmanned ERV-2 in Mars orbit, with transit habitat and fuelled TEI stage.	Same launch procedure and aerobrake manoeuvre as for ERV-1 (26 months earlier).
October 2009/ August 2010	Unfuelled MAV-2 (empty ascent stage) on MAV-1 site + propellant production module + nuclear reactor.	Same launch procedure and aerobrake manoeuvre as for MAV-1 (26 months earlier); redundancy with surface rendezvous of MAV-2 and MAV-1 elements.
Mid-November 2009/ June 2010 [ascent: October 2011/return: mid-2012]	Manned Habitat 2 on Mars surface + 6 crew members + EVA equipment + science instrumentation.	Same launch procedure and aerobrake manoeuvre as for Habitat 1 (26 months earlier); return to Earth with fuelled MAV-1 which docks with ERV-1.

ERV: Earth Return Vehicle
EVA: Extra-Vehicular Activity
MAV: Mars Ascent Vehicle
NTR: Nuclear Thermal Rocket
TEI: Trans-Earth Injection

*Following NASA reference mission of March 1997 with an estimated cost of less than $25 billion.



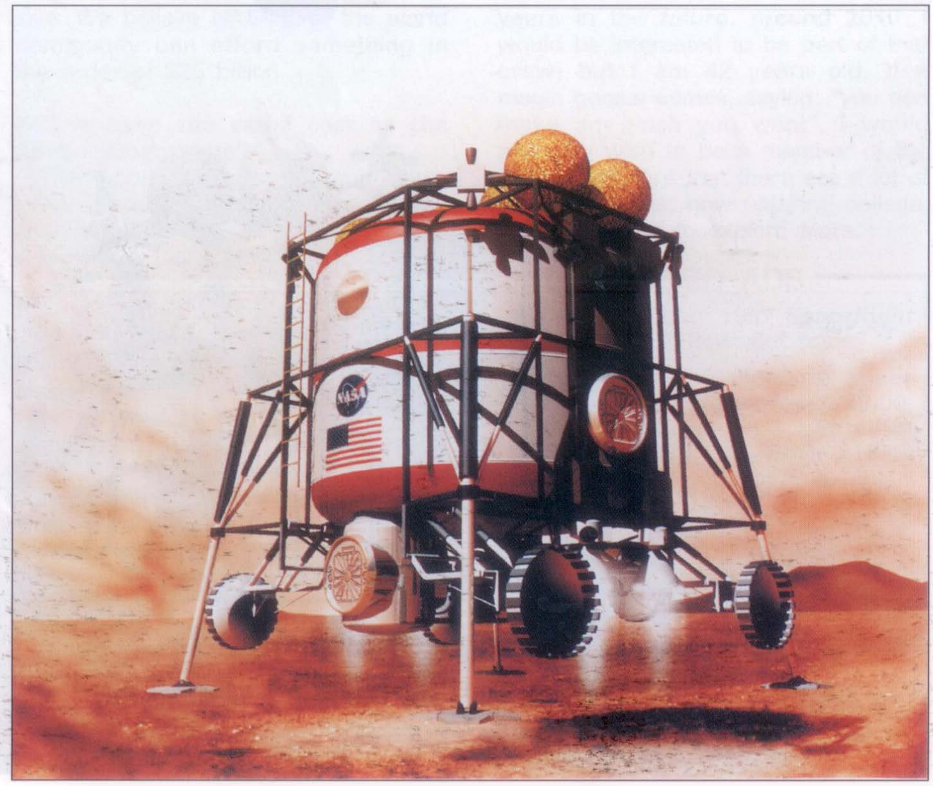
Two Mars ground habitats will be connected to create the first outpost at the surface of the Red Planet; unpressurised rovers will be used for local exploration. NASA/JSC

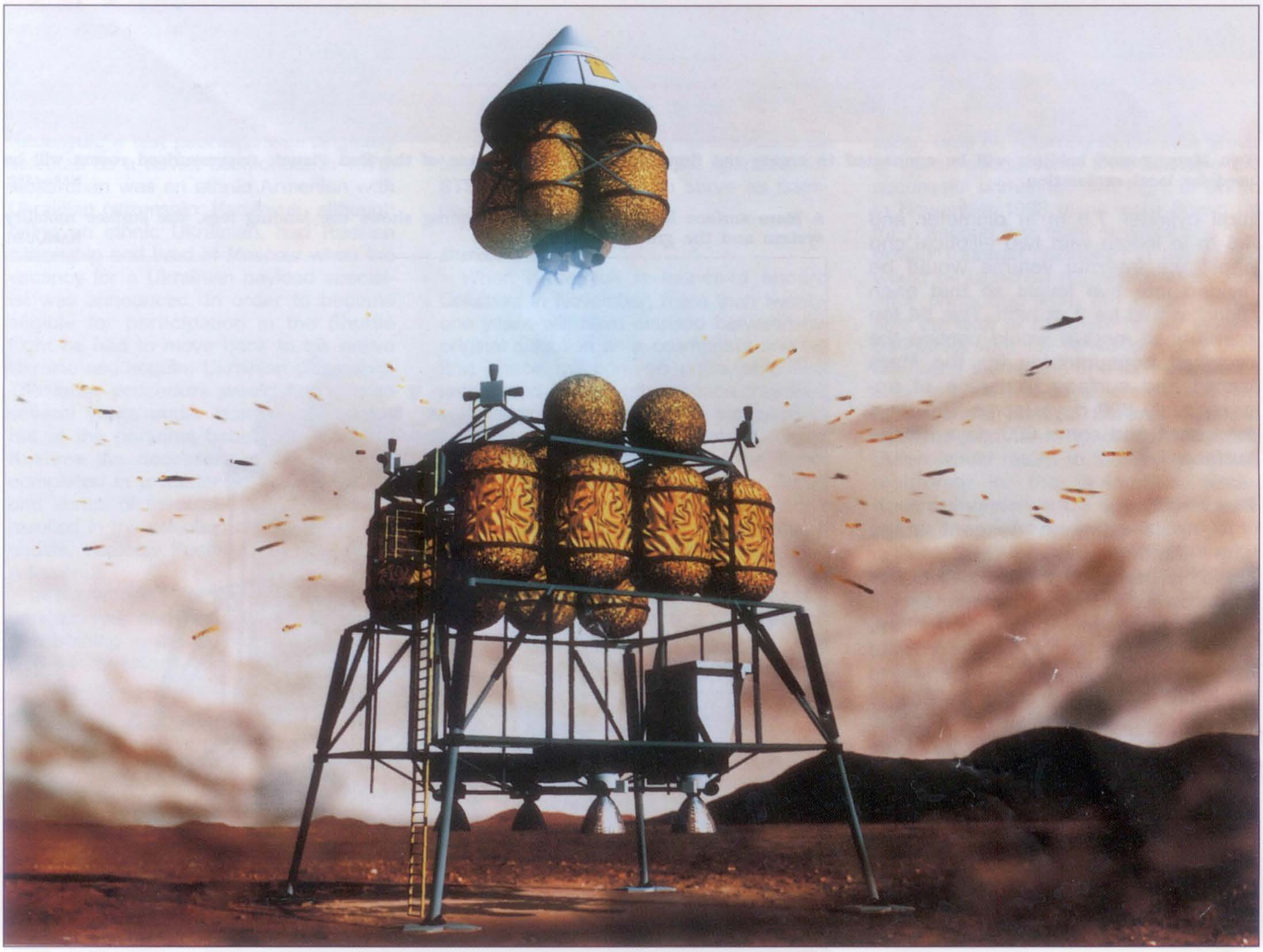
tural cylinder 7.5 m in diameter and 4.6 m in length with two elliptical end caps; the internal volume would be divided into two levels so that each "floor" would be 3 m high. This 54 ton pressurised module would contain the required consumables for the Mars transit and surface transition of approximately 800 days (some 180 days for transit and some 600 days on the surface).

Descent Stage

A single common descent stage with identical landing systems or lander is proposed for the delivery of all hardware systems (habitats, ascent vehicle, propellant production plant, surface cargo). Its role is to complete the descent-to-landing manoeuvre once the biconic aeroshell ceases to be effective. It consists of a basic structure to which other elements, including payload, are attached, a parachute system, a propulsion system and a surface mobility system. The propulsion system employs four RL10-class engines modified to burn LOX/CH_4 (methane) to perform the final 500 m/s of descent velocity change prior to landing. The descent lander is ca-

A Mars surface lander just prior to landing shows the landing legs, the surface mobility system and the ground habitat. NASA/JSC





pable of placing some 65 tons of cargo on the surface.

Mars Ascent Vehicle (MAV)

This is delivered to the Mars surface atop a cargo descent stage, but it lands with its propellant tanks empty; it consists of the propulsion system and the pressurised capsule. The propulsion system could use two RL10-class engines modified to burn LOX/CH_4 (379 s of specific impulse); it would require 26 tons of propellant to accomplish the 5.6 km/s of velocity change for a single-stage ascent to orbit and rendezvous with the previously deployed ERV.

Earth-Return Vehicle (ERV)

This remains in Mars orbit and allows the six-person crew to come back to Earth. It is composed of the TEI (Trans-Earth Injection) stage, the Earth-return transit habitat (with a 30 kW solar power system) and the ECCV (Earth Crew Capture Vehicle) capsule. The TEI propulsion system proposed in the reference mission scenario is the use of two RL10-class engines modified to burn LOX/CH_4 (the same engines for the descent and ascent stages). The ECCV, similar in concept to the Apollo Command Module, will have an estimated mass of 5.5 tons.

Above left: **Parked near the Mars Ascent Vehicle and the in-situ propellant production plant is the large pressurised surface rover for long-distance exploration trips on Mars.** NASA/JSC

Below left: **The Mars Ascent Vehicle, with its manned capsule, lifts off from the Martian surface with the in-situ produced propellant to rendezvous with the Earth Return Vehicle in Martian orbit.** NASA/JSC

Life Support

The long-time Life Support System (LSS) adequate for a six-person crew for 600 days on the Martian surface could be a hybrid combination of these options: open loop, physical processes/chemical reactions, bioregenerative "greenhouse", cached stocks of consumable materials with In-Situ Resources Utilisation equipment.

In-Situ Resources Utilisation (ISRU) Equipment

This would provide propellants for the MAV and cached reserves for the LSS. It would include two virtually redundant ISRU plants, the first delivered before the initial piloted mission and the second delivered prior to the first follow-up mission. Each ISRU plant would produce for at least two MAV missions; for every MAV mission, a plant is required to produce 20 tons of oxygen and methane propellants at a 3.5 to 1 ratio.

Surface Power Systems

These have to meet the evolutionary power requirements of the outpost to support the propellant manufacturing facility and the surface habitats. The reference scenario evaluates nuclear and solar power plants and gives preference to a SP-100 type, low-temperature nuclear source, integrated with a mobile platform and configured with a completely enveloping shield for remote deployment. Deployed to a site at least 1 km from the base, the 14 ton nuclear power plant has to be capable of delivering 160 kW.

Surface Mobility

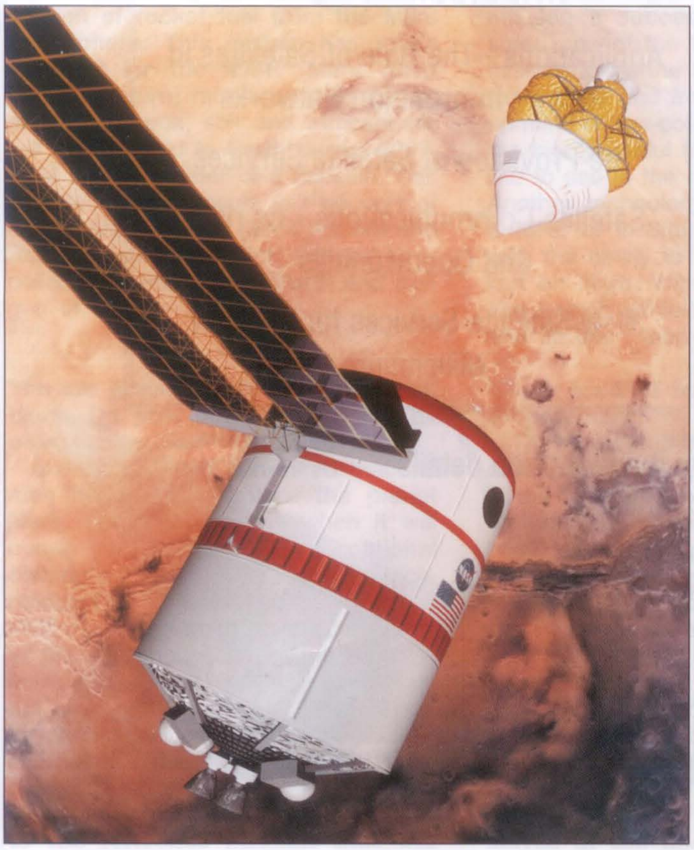
Such systems are essential for basic maintenance and operations activities as well as for exploration of the surface. Prior to the first crew's arrival, automated rovers will be used. Three classes of mobility systems, based on the time and distance to be spent away from the surface habitats, are identified:

- EVA portable LSS for 6 to 8 hour activities in the immediate vicinity;
- Astronauts assisted by unpressurised self-propelled rovers for local vicinity (distances beyond 1 km and less than 10 km from the habitats);
- Use of 2 to 4 person pressurised rovers and of small teleoperated rovers for activities on a regional scale (a radius of up to 500 km, allowing 10 days of drive plus 10 workdays to be spent at a particular remote site).

The unpressurised local roving vehicle will be conceptually the same as the Apollo lunar rover; it will be powered by a primary fuel cell (with methane and oxygen produced on Mars). The long-range pressurised rover is a mobile facility with a mass of 16.5 tons and with a continuous power estimate of 10 kW. ■

See p.417 for "Man Will Go To Mars".

The Mars Ascent Vehicle, with its manned capsule for six people, rendezvous and docks around Mars with the transit habitat of the Earth Return Vehicle. NASA/JSC



The Apollo-type Earth Crew Capture Vehicle (ECCV) returns to the Earth's surface on a steerable parafoil. NASA/JSC

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Apollo 17

The Sixth and Final Moon Landing in December 1972

I recall being in the lower 6th at school and following the mission. I stayed up three nights in succession to listen to the Voice of America's live radio coverage of the moonwalks. This article is a commemoration of the Apollo 17 anniversary using my own audio tape recordings from launch to splashdown as my main source of reference.

BY GEORGE A. SPITERI, FBIS
West Midlands

APOLLO 17 was commanded by veteran Eugene Cernan, together with rookies, Lunar Module Pilot, geologist Harrison 'Jack' Schmitt and Command Module Pilot, Ron Evans. The landing site chosen was the valley of Taurus-Littrow.

The countdown went smoothly, the only problem being a strike threat by about sixty technical workers demanding more pay that could have delayed the launch for a month but was amicably resolved.

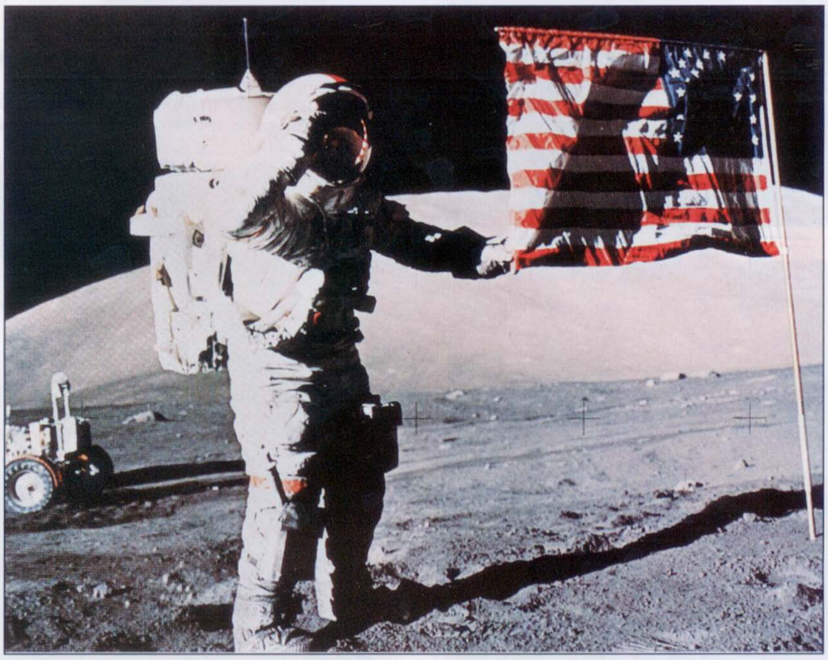
The launch itself was stopped with 30 seconds to lift-off when a failure occurred in the electronic timer that controls the count in the final three minutes. The crew waited for over 2˚ hours whilst engineers at KSC, Marshall and other centres worked to resolve the problem.

Lift-off for Apollo 17 was at 05:33 GMT 7 December and as KSC Public Affairs commentator Chuck Hollingshead reported at launch time the Saturn V rocket lit up the surrounding area, "it's almost like daylight here at Kennedy Space Center".

The coast to the Moon was uneventful and was highlighted by Jack Schmitt giving a geologist's perspective to his description of Earth as it receded from them en route to the Moon.

The Lunar Module Challenger undocked from the Command Module America on 11 December; Cernan and Schmitt landed Challenger at 19:54 GMT 11 December. It may have been the sixth Moon landing but for the astronauts the excitement was as intense as ever. "The Challenger has landed... we is here. Man, we is here!" Cernan radioed once having settled the Lunar Module at Taurus-Littrow.

The first of three planned EVAs began at 00:05 GMT on 12 December when Cernan became the 11th man to step on to the Moon. His first words, perhaps not as historic as Armstrong's, were nonetheless equally evocative: "I'd like to dedicate the first step of Apollo 17 to all those who made it possible". Schmitt joined him moments later and became the first geologist on the lunar surface, much to the chagrin of Joe Engle, whom Schmitt replaced due to the strong pro-geology lobby at NASA. The astronauts deployed the traditional US flag, however this flag, like many things on this mission was full of symbolism. It was the flag that had been on display at Mission Control since Apollo 11. The final ALSEP station was also placed on the Moon but it was a more advanced component, containing many new experiments such as the Lunar Surface Gravimeter to study the gravity waves predicted in Einstein's theory of evolution. NASA announced that this experiment was only a partial success. From a non-scientific point of view, the first EVA was remembered by many for Cernan and Schmitt's duet on the Moon, singing a rendition of "I was strolling on the Moon one day, in the merry, merry month of May...December!"



Eugene Cernan, commander of the Apollo 17 lunar landing mission, salutes the flag during the first EVA at the Taurus-Littrow landing site. NASA

What still remains the last moonwalk by man occurred on 13 December. It ended with Cernan and Schmitt collecting a total 250 pounds of moonrock and a total of 23 hours 12 minutes of EVA time.

With Schmitt already back inside Challenger, Cernan made a final speech before climbing up the Lunar Module's ladder, "History will record, America's challenge of today has forged man's destiny of tomorrow... God speed the crew of Apollo 17".

Challenger's lift-off from the Moon was shown live thanks to the TV on the Lunar Roving Vehicle that was parked a few feet away from the spacecraft. With Challenger re-docked and then finally jettisoned from America on the trans-Earth coast, Ron Evans performed an EVA on 17 December to retrieve film cassettes from the experiments he had been conducting in lunar orbit. Evans enjoyed his 45 minute EVA, "Talk about being a spaceman; this is it".

Apollo 17's Command Module splashed down in the Pacific at 1925 GMT on 19 December, three miles away from the recovery ship USS Ticonderoga.

Apollo was over, Kennedy's goal of 'landing a man on the Moon and returning him safely to Earth' had been accomplished and repeated five successful times.

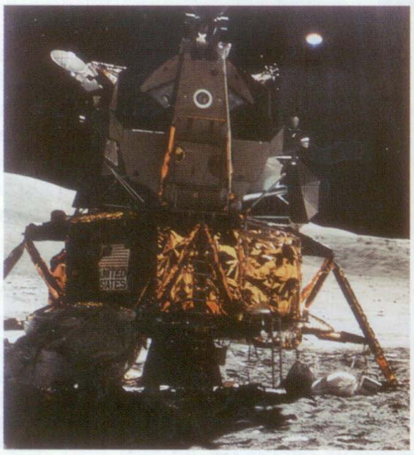
I feel privileged to have lived through a time when I was able, via the medium of TV and radio, to follow man's first tentative steps into the universe.

I give the final words to BBC's voice of Apollo, James Burke, who referred to the fact that children being born at that time would not experience the thrill of the Moon landing, "We are the ones who have lived through these years of history", he said after Apollo 17's successful splashdown. ■

APOLLO-17:

Twenty-five years ago, astronauts Gene Cernan, Ron Evans and Jack Schmitt made man's last voyage to the Moon in this century. Apollo 17 was the grand finale of one of the greatest adventures of our time. In the November issue we looked at the preparations for this mission, while this month's centre pages deal with the flight itself.

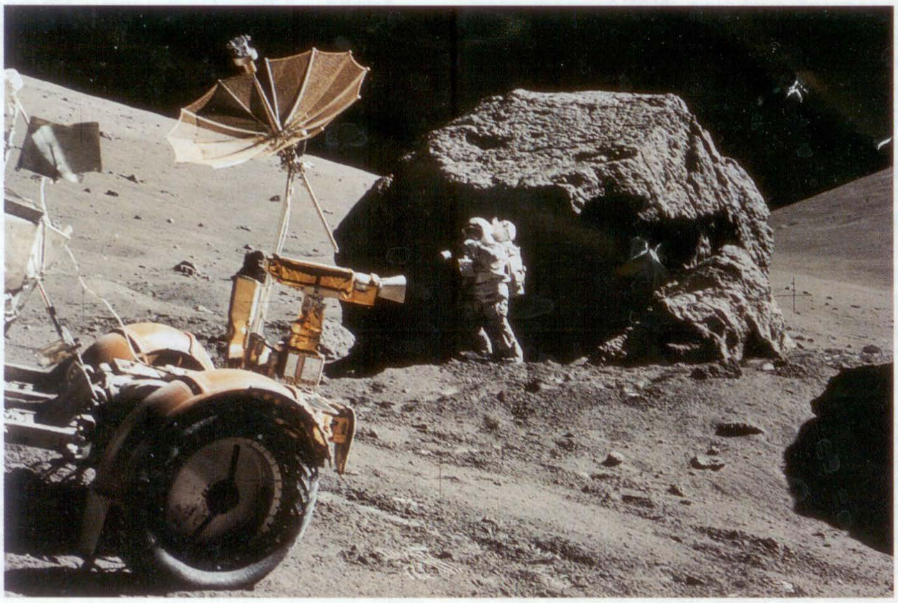
Left: After launch on 7 December 1972, Apollo 17 set course for the Moon. For the first time the trajectory of an Apollo made it possible to photograph the Earth's south polar ice cap during the three-day translunar coast. This picture was made by Ron Evans and shows Australia just below the centre of the disc, with a sizeable portion of Antarctica below that.



On 11 December the lunar module Challenger with Cernan and Schmitt aboard touched down in the Taurus-Littrow valley on the southeastern rim of Mare Serenitatis, only 200 m from the planned location. A few hours later Cernan climbed down the ladder and said: "I'd like to dedicate the first step of Apollo 17 to all those who made it possible".

The first order of business was to unload the lunar rover that would transport Cernan and Schmitt to the far corners of the valley. As Cernan made a short test drive he reported: "Houston, Challenger's baby is on the road". After loading up their equipment the men deployed a number of scientific instruments and began their geologic excursions.

Over the next three days Cernan and Schmitt performed three extravehicular activities (EVAs), totalling more than 22 hours. Ouring that time they took 2,000 pictures and collected about 110 kg of lunar samples. Geologist Schmitt is shown here during EVA-2, while he has put his gold visor up to examine a piece of Moon rock better.

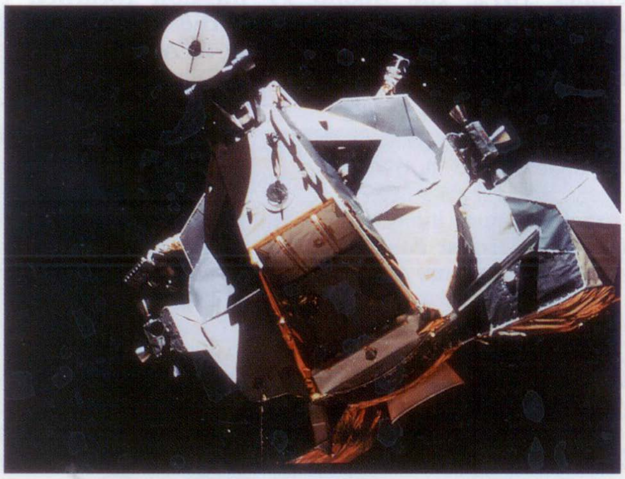


This picture shows the tired face of Gene Cernan, the last man to walk on the Moon, who had removed his hehnet inside the lunar module after the completion of surface activities. It is reminiscent of a similar photo taken three years earlier, showing Neil Armstrong after he became the first man on the Moon on 20 July 1969.

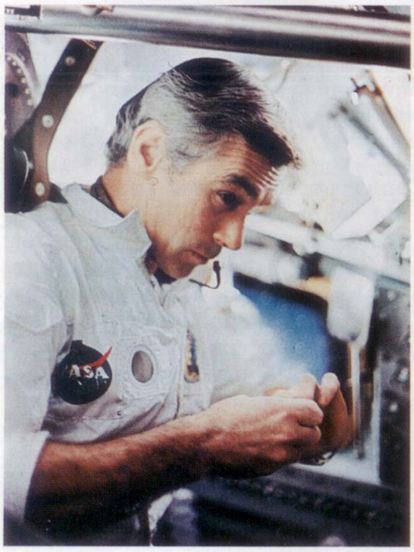
The Last Men on the Moon (Part 2)

BY ED HENGEVELD
The Netherlands

All photos NASA.
Thanks to Debbie Dodds of JSC's media resource center, Margaret Persinger of KSC's still photo department and NASA HQ's audio visual section.

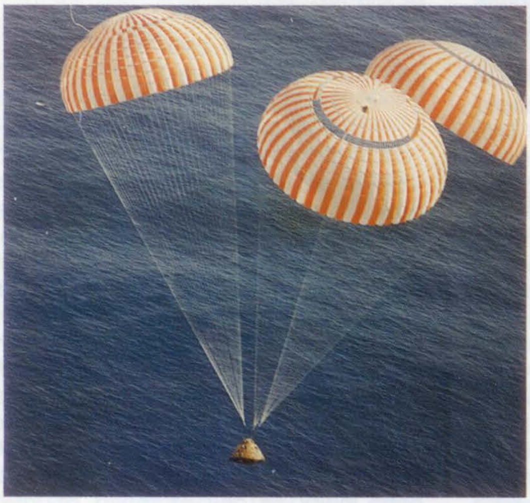


Right: **After 75 hours on the Moon, Challenger's ascent stage lifted off on 14 December to rendezvous with Ron Evans in the mothership America. This photo was taken by Evans as the two spacecraft prepared to dock. Cernan's helmeted head is visible in sunlight through one of Challenger's triangular windows.**



Left: **On 16 December, almost four years after the Apollo 8 astronauts became the first to enter lunar orbit, the Apollo 17 astronauts were ready to come home. America's big engine burned for 2 minutes 23 seconds to put the spaceship on a course back to Earth. Gene Cernan is shown here relaxing in preparation for one final major task on the way home.**

Right: **On 18 December, still nearly 290,000 km from Earth, Ron Evans performed a spacewalk to retrieve the cassettes of the panoramic camera, mapping camera and lunar sounder equipment from the scientific instrument module (SIM) bay on the outside of the spacecraft. These contained thousands of photographs and measurements made in lunar orbit. Shown here wearing Cernan's red-striped helmet visor, Evans stayed outside for over an hour.**



Above: **Splashdown on 19 December 1972 successfully concluded the final lunar landing mission in NASA's Apollo programme. This overhead view was taken from a recovery helicopter seconds before the command module hit the waters of the Pacific Ocean. "Hello recovery, it's a beautiful day", came a voice from the spacecraft. The flight had lasted 12 days 13 hours and 52 minutes.**

Right: **Less than one hour after splashdown astronauts Cernan, Evans and Schmitt were welcomed aboard the recovery ship USS Ticonderoga. Apollo 17 was over. The last men to walk on the Moon in this century had returned safely to Earth. Project Apollo is best summed up in the words of Jack Schmitt as he prepared to step off the lunar surface for the last time: "Leaving the planet Earth and going forward into the universe, I think no more significant contribution has Apollo made to history".**

In Commemoration of the 25th Anniversary of the last Apollo Lunar Mission. . .

Future History

On 17 December 1972, the Apollo 17 mission returned to Earth to conclude the final human exploration of the Moon. The final Soviet uncrewed Luna space probe stopped operating in August 1976. Humankind's first attempts to explore a world, other than Earth, had come to an end.

BY JOHN CATCHPOLE
Hampshire, UK

ONE DAY HUMANS will return to the Moon. When we do we will initially establish scientific bases, mine its minerals and, ultimately, we will colonise its surface. In the distant future the Moon might even become a tourist destination. The present hiatus in lunar flights gives us time to take stock of what we have already achieved and to make the necessary preparations for our return to the Moon.

When humans do return to the Moon there will be those amongst them who will want to make a quick profit. These people will want to desecrate the original landing sites and sell items left behind by the original lunar explorers for vast sums of money back on Earth.

There will always be those ready to pay for a piece of space flight history. You have only to consider the auctions of space memorabilia in recent years. One Soviet Lunokhod, resting on the lunar surface has already been auctioned into private ownership, although the price did not include its return to Earth. The Hall Of Economic Achievements' unique Soviet space hardware collection, once housed in Moscow but sold for hard western cash, is another prime example. There is a vast international market for historic space objects.

If you doubt the truth of my words, just imagine that you have limitless wealth and then ask yourself, how much would you be willing to pay for the overshoe from Neil Armstrong's left boot? That is to say the overshoe that made the famous "One small step for a man, one giant leap for Mankind." What price would you put on the Portable Life Support System that kept Armstrong alive during his extravehicular activity? These priceless historic relics are both still on the Moon, at Tranquillity Base, just waiting for some future entrepreneur to pick them up, return them to Earth and offer them for sale.

The American hardware legally belongs to the National Aeronautics and Space Administration (NASA), and the Soviet hardware is owned by the Russian Space Agency, both of which are government departments. Who is to say that those governments will not want to return their hardware to Earth one day and put it on display? Now, while no Humans are presently flying to the Moon, is the time to protect the Historic Lunar Sites that already exist for all time. The United Nations should be called upon to draw up international legislation to protect these sites and make it a crime to remove anything from them, or to disturb them in any way.

Such legislation has a precedent in the international laws governing the exploration of the Antarctic continent, as well as the international law that already covers the exploration of space. The Moon is an international body, to which no one nation can make a national claim. Perhaps the Historic Lunar Sites could be protected by an extension of this legislation. The new legislation must be strong enough to prevent items auctioned into private ownership being removed from the lunar surface. Salvage laws must not apply to these sites. The details must be left to the lawyers to work out.

Future Human visitors to the Moon will want to visit these sites because of their historical significance. This must be allowed. However, visitors will have to be kept at a safe viewing distance, so that they do not interfere in any way with the original exploration site. Perhaps they should not be allowed to approach within two or three metres of any original footprint, tyre track, hardware, or impact site.

In the future the Historic Lunar Sites might be enclosed in clear viewing structures. Personally, I feel that isolating these Historic Lunar Sites from the lunar environment by enclosing them in some sort of permanent viewing structure would take something away from them. My preference is to keep the historic site exposed to the vacuum but have enclosed walkways.

All of the present sites where hardware from Earth rests on the lunar surface are directly connected with Humankind's first footfall on another world. Regardless of their Soviet or American origin each of these pieces of hardware was a part of the race which culminated in Lunik II's first destructive impact on 14 September 1959 and ended with the Lunar XXIV mission in August 1976. Somewhere in the middle, on 21 July 1969, Human beings left their footprints on the surface of an unexplored world.

The Historic Lunar Sites are unique! They will remain unique, no matter how many astronomical bodies humans may walk on in the future. Never again can humankind reach out from Earth and make its first ever landing on another world. Never again can we take our first ever steps on an astronomical body other than Earth. These unrepeatable achievements were completed during this first era of lunar exploration. With the exception of the Surveyor III site, no humans have been back to any of these Historic Lunar Sites, so we now have the opportunity to preserve them for all Humankind.

The twenty fifth anniversary of the last Apollo astronauts leaving the lunar surface is an appropriate time to begin thinking about such things. If we are to do this we should do it now, before humans return to the Moon !

About the Author

John Catchpole

John Catchpole was twelve years old when Apollo XI landed on the Moon and began his interest in space flight. Since that time he has remained fascinated by the Apollo Moon landings, whilst following current events in space. He strongly believes that the early lunar programmes were unique in Humankind's history as they represent our unrepeatable first steps in the exploration and colonisation of the Universe. As such, he feels that these sites should be preserved and legally protected for all Humankind. John has had a number of magazine articles, on a variety space related topics, accepted for publication.

One-page INTO SPACE articles offer readers the opportunity to express their ideas and 'think aloud' on space topics which they see as important and of interest to others. Contributions of an appropriate (one-page) length may be sent to the editor at any time and should be accompanied with a photo of the writer (head and shoulders) and a few lines of personal details.

Man Will Go To Mars

Slow Trajectories for Unmanned Modules and Supplies: Fast Trajectories for the Crews

"Around 2002 and 2003, a technological plan for an international project of human missions to Mars will be presented for 'go no-go' decision from governments."

DAVID KAPLAN, EXPLORATION OFFICE, JSC

BY THEO PIRARD
Belgium

Introduction

The Exploration Office at NASA Johnson Space Center, Houston, is looking at possible approaches for human missions to explore the Moon and Mars. Since 1988, David Kaplan, an aerospace engineer, has been working in this office to elaborate NASA planning for manned space flights to the Red Planet. Before coming to JSC, he worked at JPL on the design of the interplanetary Galileo mission, then at NASA headquarters on the initial concepts of the Space Station. In 1984, he moved to JSC for the Space Station project and was in Mission Control as Space Shuttle Flight controller.

Since 1993, Kaplan has been especially involved with the development of the new technology, called ISRU (In-Situ Resource Utilisation): this programme intends using the materials and resources on the Moon or on Mars to reduce costs and risks of missions in the Solar System. He is the manager for an experiment which will fly to Mars aboard the JPL Mars Surveyor Lander in the year 2001 in order to test the system for in-situ production of rocket fuel from the Mars atmosphere. This system has to be qualified for the MISR (Mars ISRU Sample Return) mission: up to 2.5 kg of Martian rock, soil and atmosphere will be returned to Earth during 2007-2008 in the canister of a capsule. This sample return capsule will be part of a two-stage MAERV (Mars Ascent and Return Vehicle), which will be propelled by propane from Earth and oxygen of Mars.

* * *

You are preparing an experiment on Mars. Do you believe that in the near future Man will go to Mars?

Absolutely, I am convinced that human beings will explore the planet Mars. The only issue is when it will occur. NASA and the international community have to develop the technologies to help to reduce the total cost of a mission to Mars. They have to prepare the scenarios so that the politicians in the 2001-2002 timeframe will have all the information they need to reach a political decision to send an international mission to Mars.

How many people have contributed to the reference mission that will be proposed to NASA and the international community?

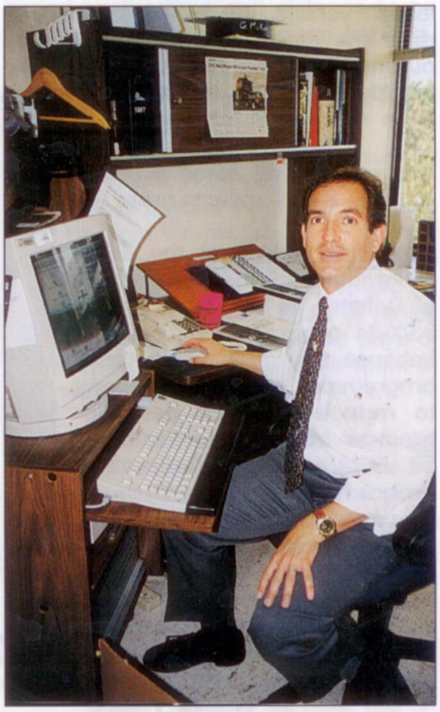
Difficult question to answer. There are about 12 people who are members of the Exploration Office at JSC. We act more as an internal network with teams at other NASA organisations, research centres, other academia, universities and industries.

Compared to the International Space Station, which challenging technologies are required for a human mission to Mars?

One of the interesting features about human missions to Mars is the length of time we plan to stay on the surface. There are really two options. You can either stay on Mars for 14 to 30 days or you have to stay for 500 to 600 days. We have not yet reached any final decision. Our reference mission is to have human crews on the surface of Mars for 500 days. So the technologies of highly reliable life support systems are crucial to make the mission a success. We also understand one of the biggest costs of the mission to be the launch of spacecraft from Earth and from Mars. The development of low-cost launch vehicles is the highly useful technology we would like to see in the next couple of years. Another technology I am interested in is ISRU or In Situ Resource Utilisation with the ability to manufacture propellant on Mars. With this possibility, we can launch vehicles with empty tanks and fill them there.

Which kind of fuel will you be able to produce?

The easiest thing to do is to produce oxygen using the carbon dioxide in the Mars atmosphere which is 99% carbon dioxide. If we did only that, we have to bring a fuel such as propane from Earth. For every kilogram of propane you bring, you need 4 kg of oxygen. You would be able to produce on Mars 80% of the overall mass of required propellant. But you could also take with you from Earth hydrogen and with the hydrogen, you could convert Martian carbon dioxide into methane and oxygen.



David Kaplan at the time of the interview at the Exploration Office, JSC. Th.P./SIC

Maybe in the underground of Mars, you would find some useful materials?

We are very excited about these materials. We think that there is a permafrost, that frozen water is underneath the surface of Mars. When you look at orbital photographs, you see clear evidence of large qualities of water that flowed on Martian surface in the distant past. The observations made by Mars Pathfinder show evidence of a dry river and a lake bed. We know that water was somewhere. We know that some of the water is frozen in the North and South caps. Even so, there is a tremendous amount of water that we cannot yet find. We could determine through robot missions where the packets of water are. From water, by electrolysis, hydrogen and oxygen can be produced. They are high performance propellants. We have water for people and water is a very good protective insulation against radiation.

The main problem is the flight from Earth to Mars. Do you need heavy, powerful, expensive launch vehicles such as Saturn V and Energia, now abandoned?

Well, if there were several options for Mars exploration, we would like to

have a large, heavy launch vehicle. That would allow us to reduce the amount of Earth orbital operations. We would generally rather not have orbital rendezvous, docking and construction in Earth orbit, because this adds complexity. On the other hand, to build a new large launch vehicle can be an expensive proposition. Another alternative is to use some Shuttle-derived vehicle such as a cargo version of the Space Shuttle where perhaps in two launches you place in Earth orbit what you could take up with one heavy launch vehicle. We would try to minimise the amount of construction by putting together the elements very quickly and easily with the minimum number of interfaces.

David Kaplan describes the MISR (Mars ISRU Sample Return) mission. ISRU stands for In-Situ Resource Utilisation which involves the development of new technology including in-situ production of rocket fuel from the Mars atmosphere. Th.P./SIC

Are you taking some interest in the EELV programme of DOD?

We are looking at the EELV programme of the Department of Defense as well as at the X-33/X-34 programmes of NASA, because the intent of all those programmes is to find the way to reduce the cost per kilogramme launched to Earth orbit. EELV and X-33/VentureStar do not have the large lift mass we would like to see. But if they can be developed, they will improve low-cost transportation with larger vehicles. The key is low-cost access to space.

You are considering the use of the Energia launch vehicle. Does it mean that you have contact with RKK Energia and the Russian Space Agency for possible cooperation to use Energia technologies?

Certainly no. Some of our graphics show the Energia rocket because it has the lift capability that we will be interested in. We use it to inform others of the capabilities available in the world to accomplish an international mission to Mars. Truly, we did speak directly with Russia, but we did not visit Baikonur. We are just considering the advantage of the lift capability offered by the Energia rocket.

The most sensitive thing in this venture would be the use of nuclear systems. Why do you contemplate such a high risk energy source?

We feel that a human outpost on Mars must have sufficient power to function. As we are talking now, the Mir space station is crippled because it has only 50% power. We want to be in a position to allow crews on Mars to have abundant energy. One choice was to take solar arrays but we would have to have a football pitch-sized array in order to produce 150 kW of power on account of the dust problem. Or you could have a very small compact nuclear source. We will launch that nuclear source before it is activated: if there is a catastrophe on the launch pad, it will not yet be radioactive and there will be no problem. Radioactivity can be sealed inside explosion-proven canisters to make sure that in the event of a dramatic launch, all these containers will be recovered.

To reach Mars, will you use advanced propulsion with a nuclear reactor? Will you revive the NERVA programme of the 1970s?

The NERVA programme which was tested in the 1970s was stopped for several reasons, one being the environmental hazard as the people at that time did not have the technologies that we do today. We find today that the transfer orbit to Mars could benefit greatly from having this kind of nuclear rocket. How do you make nuclear propulsion environmentally safe? The answer to this question is to make sure that the nuclear rocket is never low in Earth orbit. We have to reach an orbit with a decay lifetime of 1000 years.

Will this nuclear rocket be reusable to travel from Earth to Mars?

We have to reuse it in a high Earth orbit, in order to avoid the radioactive effects of a catastrophic explosion. To use this rocket repeatedly from Earth to Mars is one idea. We are looking at it. Mars explorers would be launched with traditional spacecraft to rendezvous and dock with the nuclear vehicle.

Will such a system be used close to Mars?

Again for safety reasons, the nuclear vehicle has to enter a high Mars orbit. The crew use chemical engines to descend to Mars. When they come back, they could rendezvous and dock in high Martian orbit with the nuclear propulsion system for the return to Earth. On approaching Earth orbit, the crew has to use a vehicle with more traditional chemical propulsion.

Can you summarise the reference scenario for a human expedition to Mars?

The key thing is that we want to take advantage of slow trajectories and fast trajectories from Earth to Mars. The opportunity to travel from Earth to Mars occurs only every 26 months. Before we send humans, we would like to launch unmanned elements to Mars: the Earth Return Vehicle that the crew would eventually use to return to Earth, the Mars Ascent Vehicle that the crew would find at the surface, the habitat module with science equipment, water, supplies, food for 500 service days. Those three missions with heavy payloads would be launched on a slow and low-energy trajectory that would take between 10 to 12 months to get to Mars. The return vehicle will be placed in Mars orbit, while the ascent vehicle and the habitat will be installed at the surface. Twenty-six months after these robotics missions, it will be time to launch the crew to Mars. The fourth mission would concern the transit habitat crewed by 6 to 8 people: they would travel to Mars on a sprint trajectory. This will allow them to get there in 4 to 6 months, and so avoid a lot of disagreeable effects in zero gravity and with the radiation environment of space.

When the crew arrives, will they land near an active habitat and find an ascent vehicle filled with fuels that have been produced from Martian atmosphere?

Correct. The great value of the ascent vehicle is that it arrives empty at Mars. It will deploy a small light-weight plant for propellant production. During the 16 months before the crew leaves, we will fill the tank on this ascent vehicle with the propellants. Right now, our favourite is a combination of methane and oxygen but it could change if we do more research. However, should there be a problem or should, for any reason, the crew land somewhere on Mars not within a reasonable distance of the predeployed resources, we would have the opportunity to use the Earth Return Vehicle and Mars ascent vehicle which are intended for the second crew. These would have been launched in the same window as crew No. 1, but on a slow trajectory to Mars, taking advantage of minimum energy. If after about 4 to 6 months, the first human crew gets in trouble and lands somewhere in error, they can still contact the robotic outbound for Earth to land within their area.

A permanent outpost will be on Mars, but it will not be permanently inhabited?

The first two crews will not overlap

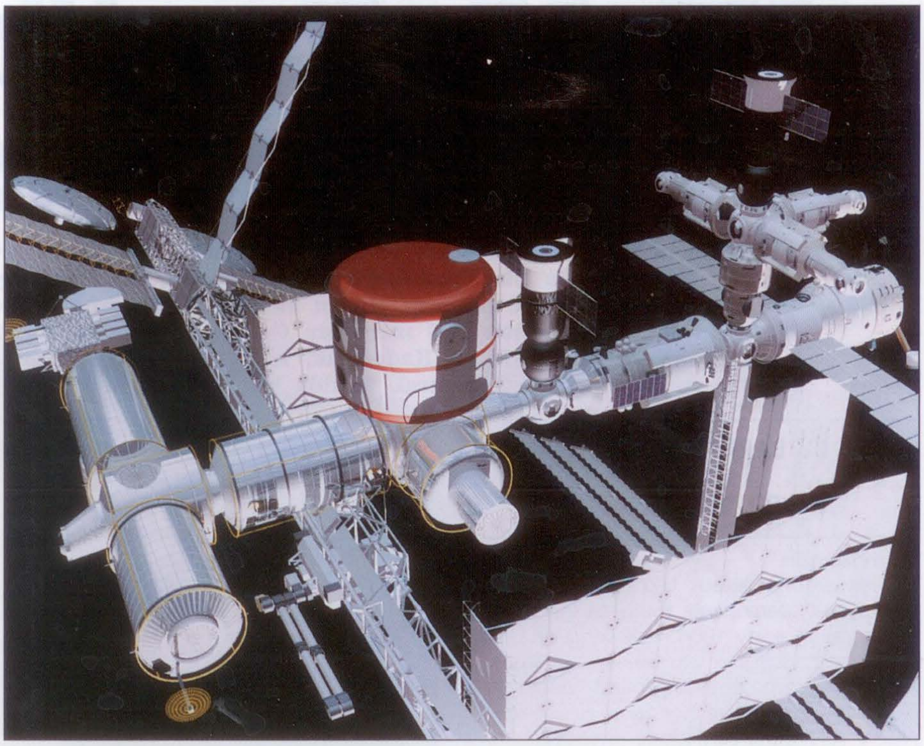
for service days. When crew No. 1 reaches the end of its mission, it puts the Martian surface facilities in a quiet mode for several months before crew No. 2 arrives and takes charge of them. While crew No. 1 is flying back to Earth, crew No. 2 is in transit, leaving the Earth. Another habitat will land, so that we will have three habitats on Mars. The additional crew will build a real outpost. Our vision is that, at the end of the third human mission to Mars, we will reach the point for deciding whether to continue on-going manned expeditions or to establish a permanent human presence on Mars or to stop the exploration of Mars, like we did for the Apollo missions.

What is the timeline for this ambitious project, from reference mission to outpost establishment?

It is a difficult question. The American President and Congress have not authorised NASA to do anything. What I tell you is a planning date. We believe that somewhere around 2002 and 2003, a technological plan with economical impact has to be completed at an international level. We have to understand all the technologies that will be required for missions to Mars and they have to have been developed to a point of readiness somewhere in the world. We also need to have a very good estimate of costs and to have a work breakdown of who will do the various components. Which portion from Russia, from Japan, from ESA? We need to present a plan to all of the governments, in order to get their 'go no-go' decision. Basically, about seven years after the decision is made to go to Mars, we believe we can have the first launches of the robotic infrastructure, followed, 26 months later, by the human mission.

Do you have contacts with other space agencies, such as ESA, CNES, NASDA?

The answer is no. That is the problem we need to fix. In our internal planning, we at NASA have always acknowledged that we must have an international undertaking. We hope NASA has the leadership role but not the exclusive ownership role. We are talking with colleagues in ESA and Canada about having their representatives joining us here in Houston, to become involved in the very initial planning stage that we are doing right now. We are also interested in the capabilities and technologies that non-spacefaring countries and industries could bring to this programme. If we go to Mars and land on the surface, it involves not only the domain of aerospace engineers: once on the surface, we want to have people who understand problems of building, mining... and know about other operations which go on outside the usual aerospace expertise.



The reference scenario for human missions to Mars includes the testing of the ground and transit habitats by attaching them to the International Space Station. NASA

Let me come to the most sensitive element. What about the cost? You did not mention any figures in the document which describes the reference mission.

To be true, we did calculate the cost. Because of the sensitivities, we chose not to include cost figures in the document, which is scheduled to go to print before the end of this year. The previous value assigned to human missions to Mars was about $400 billion. We have shown that our reference mission would be at least 1/10 of this cost, somewhere in the $40 billion range. We still think that is too expensive. We believe NASA and the world community can afford something in the order of $25 billion.

Will it have the same cost as the Apollo programme?

The Apollo programme in today's dollars would be much more expensive. We hope to be about 1/10 as expensive as the Apollo programme.

How could you do it for that?

At the beginning of the Apollo programme, none of the technologies for manned space flight existed. There was no pad at Cape Kennedy for heavy launch vehicles, no understanding of life support systems. The key technologies we are working with were developed 30 years ago. To go to Mars will be a major undertaking, but we know more about life support and human behaviour than we did when Apollo began. The miniaturisation of systems saves mass and time. Let's compare the Mars Pathfinder and Viking probes. If we did the Viking spacecraft today, it would be $2 billion. Mars Pathfinder was only 220 million dollars: it was less than 1/10 of the cost. We are just more matured to undertake human exploration today than in the early 1960s. We want to discuss estimates that are within the capability of the world economy and to bring them down to be even lower than when we started the discussions internally.

You are so enthusiastic about this mission. Do you believe you will be a member of the first crew to Mars?

Oh no. I think that the crew selection for the mission to Mars is many years in the future, around 2010. I would be interested to be part of that crew, but I am 42 years old. If a magic genius comes, saying: "you can make any wish you want", I would probably wish to be a member of the crew. I am sure that there are a lot of young students, now entering college, who are going to explore Mars.

STS-87: The Ukrainian Connection

One of the crew members to fly aboard the Space Shuttle Columbia's STS-87 mission in November is Ukrainian payload specialist Leonid Kadenyuk. On this 16-day flight he is scheduled to perform eleven biological experiments jointly developed by US and Ukrainian scientists. BIS members Gerard van de Haar and Bart Hendrickx had an opportunity to talk to Kadenyuk, a former Buran pilot, and his back-up Yaroslav Pustovyi at Cape Canaveral, Florida last January.

BY BART HENDRICKX
and
GERARD VAN DE HAAR

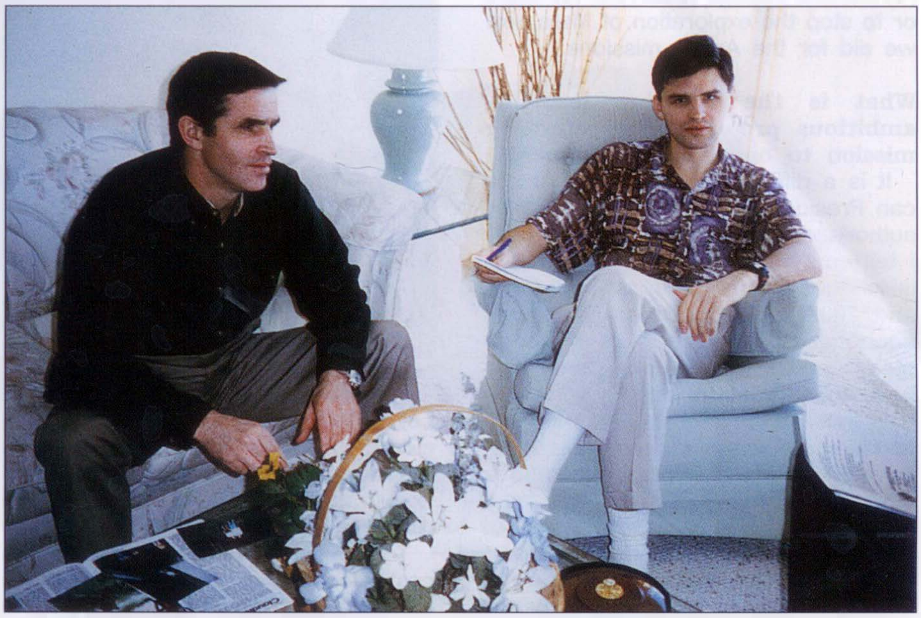
Introduction

Discussions about Ukrainian experiments and cosmonauts flying on the Shuttle began in early 1994. Following an official state visit by Ukrainian president Leonid Kuchma to the United States in November 1994, the heads of NASA and NKAU (the Ukrainian space agency) were instructed to further explore this possibility. During a return visit by President Clinton to the Ukraine in May 1995 it was officially announced that a Ukrainian cosmonaut would participate in a Space Shuttle mission in October 1997.

Ukrainian Selection

Two pairs of candidates were selected for the flight before the final choice of two payload specialists was made in 1996. A first round of medical tests in 1995 resulted in the selection of Vyacheslav Meitarchan, an engineer, and Leonid Kadenyuk, a test pilot who was originally selected as a Soviet cosmonaut in 1976. Meitarchan was an ethnic Armenian with Ukrainian citizenship. Kadenyuk, although being an ethnic Ukrainian, had Russian citizenship and lived in Moscow when the vacancy for a Ukrainian payload specialist was announced. In order to become eligible for participation in the Shuttle flight he had to move back to his native Ukraine and acquire Ukrainian citizenship. The latter procedure would have taken several years under normal conditions, but at the personal behest of President Kuchma the necessary paperwork was completed in a matter of weeks. A second series of medical tests in mid-1996 resulted in the selection of two young scientists, Yaroslav Pustovyi and Nadezhda Adamchuk.

In November 1996 the final choice fell on Kadenyuk and Pustovyi, who then began training in the United States for the STS-87 mission. On 16 May 1997 Kadenyuk was officially announced by NASA as the prime payload specialist for STS-87, with Pustovyi to serve as back-up.



Ukrainian cosmonauts Kadenyuk (left) and Pustovyi at their home in Cape Canaveral. Note the *Spaceflight* magazine on the table!

Buran Veteran

When Kadenyuk is launched aboard Columbia in November, more than twenty-one years will have elapsed between his original selection as a cosmonaut and his first space mission, an unenviable feat unmatched by any other space traveller.

Kadenyuk was one of nine test pilots of the August 1976 Air Force intake. These pilots were primarily selected for flights aboard the Soviet Space Shuttle Buran (approved in February 1976), although many of them were soon transferred to the Soyuz/Salyut programme. Kadenyuk, however, remained part of the Buran team until August 1983, when he was dismissed from the cosmonaut corps for personal reasons.

After his apparent rehabilitation in October 1988 he returned to the elite group of Buran pilots. Some time following the successful unmanned test flight of Buran in November 1988 plans were drawn up for a second test flight in which the 1K2 orbiter (dubbed "Buran-2" in the press) would be launched unmanned to Mir and after undocking from the station would link up with a manned Soyuz vehicle equipped with an APAS docking unit, simulating the rescue of a stranded Buran crew in orbit. The Soyuz crew would perform several tests of Buran's on-board systems and then fly on to Mir while Buran would return to the Baikonur cosmodrome in the automatic mode. Kadenyuk underwent a full cycle of training as one of the back-up commanders - with cosmonaut Fefelov as his flight engineer - for this so-called "Soyuz Rescue" mission, which was planned for the 1992-1993 timeframe, but was eventually scrapped due to budgetary problems.

Kadenyuk was also considered as the commander of an all-Ukrainian Soyuz-TM visiting mission to the Mir space station, discussed between Soviet and Ukrainian presidents Mikhail Gorbachov and Leonid Kravchuk in 1990, but this flight never materialised either. Now it looks like Kadenyuk's patience will finally be rewarded. At the time of his selection in 1976 he probably would have found it hard to believe that eventually he would become the only pilot of the Buran team to fly aboard a winged spacecraft and

About the STS-87 Ukrainian Cosmonauts

Leonid Konstantinovich Kadenyuk, the prime payload specialist, was born on 28 January 1950 in the Ukrainian village of Klishkovtsy. In 1971 he graduated from the Air Force Pilots School in Chernigov. During many years of training Kadenyuk flew more than 50 types of planes and became a Test Pilot First Class.

Yaroslav Ihorovych Pustovyi, the back-up payload specialist, was born in the Russian city of Kostroma on 29 December 1970. He studied at the Mozhaiskiy Military Space Academy and in June 1996 earned a PhD in radiophysics at Kharkov State University. Before his selection as a cosmonaut he worked at the Institute of Magnetism, a member of the Ukrainian Academy of Sciences.

Readers Write

Music in Space-1

Sir, Seeing the item "Cosmic Tunes" by Bert Vis in ***Spaceflight*** (Vol. 39, No. 10, October 1997, pp.342-343) had me rummaging through my record collection and I discovered the following which may be of interest to readers.

On the 1986 release *Rendezvous* by Jean Michel Jarre is a piece entitled *Last Rendezvous: "Ron's Piece"*. It contains a saxophone solo played by one Pierre Gossez. The sleeve notes add the following:

> "This piece was specially composed for Ron to play on his saxophone in the shuttle and was to become the first musical piece played and recorded in space. Ron was so excited about this piece that he rehearsed it continuously until the last moment. May this memory of my friend the astronaut and the artist Ron McNair live on through this piece".

The Challenger disaster may therefore have deprived us of the first piece of music to be recorded in orbit for general release.

A.P. TYZZER, FBIS
Worcs, UK

Music in Space-2

Sir, In the article "Cosmic Tunes" (***Spaceflight***, October 1997, p.342) Bert Vis states "as far is known, the first to carry his musical instrument into space was Ron McNair, who flew and played his saxophone on STS-41B in February 1984".

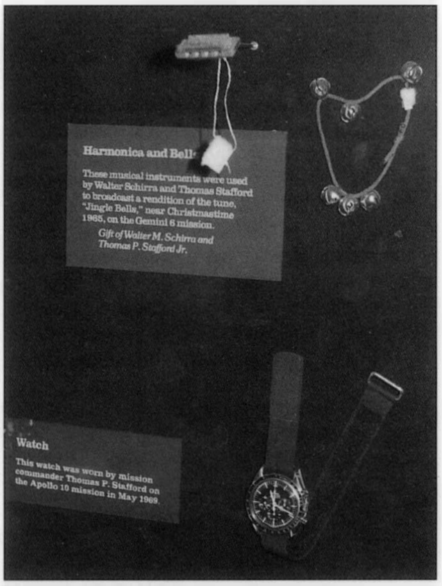
You may like to note that astronauts Walter Schirra and Thomas Stafford, while playing a practical joke about seeing Santa Claus shortly before the end of their Gemini 6 mission in December 1965, gave a rendition of the tune Jingle Bells using a small harmonica and a bunch of little bells. The harmonica was a tiny four-hole Hohner, capable of playing 8 notes, which Schirra had secured in his spacesuit by tying it to a pocket zipper with dental floss [1].

The size of these small 'instruments', shown in the accompanying photograph, can be gauged by comparison with the wrist watch also in the picture. The photo was taken last year at the Smithsonian National Air & Space Museum, Washington DC.

GEORGE D. ANDERSON, FBIS
Berkshire, UK

Reference

1. Wally Schirra and Richard N. Billings, *Schirra's Space*, Bluejacket Books, Naval Institute Press, 1995, p.165.



Bells and harmonica used by Schirra and Stafford on Gemini 6 in 1965.
GEORGE D. ANDERSON

Music in Space-3

Sir, I have read Mr Bert Vis' article *Cosmic Tunes* (***Spaceflight***, October 1997) with great interest. The first musical instrument in orbit was not the saxophone of Ronald McNair, but the acoustic guitar of flight engineer Alexander Ivanchenkov of the second main expedition to the Salyut-6 station. The musical instrument was delivered to Salyut-6 by the cargo spacecraft Progress-3 on 9 August 1978 [1]. The literary story *Guitar for Salyut* by Vladimir Gubarev, a well-known Russian "space" writer and journalist (not to confuse with cosmonaut Alexei Gubarev!), which was issued at the beginning of the 1980s in Moscow, was devoted to this episode.

LEON ROSENBLUM
Israel

Reference

1. Phillip S. Clark, *The Soviet Manned Space Programme*, Salamander Books Ltd., London-New York, 1988, p.111.

Yes, To British Astronauts

Sir, I should like to congratulate British-born Michael Foale on the magnificent work he conducted aboard Russia's Mir space station. His courage and high skills must rank high in the annals of astronautical achievement.

But why has it required a British subject to take up American citizenship to become a space shuttle astronaut, when so many governments abroad have trained their own people for Space through international programmes? Isn't it time we conceded that Space is here to stay, and ensure our own people get the chance of joining in this great adventure?

KENNETH W. GATLAND
Surrey, UK

STS-87: The Ukrainian Connection

(continued)

certainly that it would be American rather than Soviet!

US-Ukrainian Experiments

Officially called the Collaborative Ukrainian Experiment (CUE), the US-Ukrainian payload is a collection of 11 plant space biology experiments scheduled to fly in the Orbiter's middeck. It is the result of scientific cooperation between approximately 10 US and 30 Ukrainian scientists working for several US universities and the Ukrainian Institute of Botany in Kiev.

The kickoff meeting for the CUE was held at the Kennedy Space Center in November 1995. Since then scientists and engineers from NASA, Dynamac and Bionetics have been preparing the flight hardware at KSC's Hangar L. All experiments will be executed in two middeck facilities, known as the Plant Growth Facility (PGF) and Biological Research in Canisters (BRIC).

The eleven investigations consist of four stand-alone experiments and seven tissue-sharing experiments. In the PGF, several experiments will evaluate the effects of microgravity on pollination and fertilisation utilising 12-day old *Brassica rapa* (musterd plant) seedlings. Flowering will begin four days into the mission, at which time the Ukrainian cosmonaut will begin performing daily pollinations. Flowering is expected to continue through the tenth day of the mission. A simple labelling system will allow a time-course examination of the stages of reproduction in microgravity: like pollination, fertilisation, and early seed embryo development. Leaf tissue from these experiments will be used to study the effects of altered gravity on the photosynthetic function.

In the BRIC experiments, examinations of the effects on growth and defence responses in soybeans will be performed, next to a study on the effects of microgravity on moss.

The experiments also have an educational component. Curriculum enhancement materials for high school classrooms are in production and during scheduled Shuttle downlink sessions, the Ukrainian cosmonaut will speak with children on Earth who will be performing similar experiments in their US and Ukraine classrooms.

Original plans for STS-87 also called for a Ukrainian welding experiment to be performed during a spacewalk by astronauts Winston Scott and Takao Doi. The experiment was to be developed by the Paton Institute in Kiev, which has a long history of building welding equipment for Soviet EVAs. However, the decision to reassign the cancelled STS-80 spacewalks to the STS-87 mission left no time to perform this welding experiment, which was therefore cancelled.

Sources

Interview by the authors with Kadenyuk and Pustovyi in Florida, January 1997.

Y. Sokolovskaya, "Russian Colonel to Become First Ukrainian Cosmonaut" (in Russian), *Izvestia*, 17 April 1996.

I. Marinin, "Ukraine will have its astronaut" (in Russian), *Novosti Kosmonavtiki*, 12-25 February 1996, p. 62.

S. Shamsutdinov and I. Marinin, "Flights that did not take place" (in Russian), *Aviatsia i Kosmonavtika*, July 1993, p.48-49.

Acknowledgement

The authors would like to thank Mr. Peter Chetirkin at KSC's Hangar L for his contribution to this article.

Lift-Off Demonstrated

Sir, Among the astronauts and cosmonauts present at the Paris Air Show last June were STS-84 commander Charles Precourt (who, incidentally, turned out to speak French fluently) and three of "his" mission specialists - Jean-François Clervoy (ESA), Edward Lu and Carlos Noriega. In the ESA pavillion, the four astronauts, making their first public appearance after their return to Earth, gave an overview of the flight, showed the mission film and answered questions, including - in a special session - a number posed by children.

When a youngster asked them to position themselves as they had been in the Shuttle, this gave rise to a hilarious scene in which the space explorers were seen "treading water" in an area that doubled as the surface of Titan.

TON VAN ROOIJ
The Netherlands

The old Atlas-B dumped by the roadside. T. PRIBYL

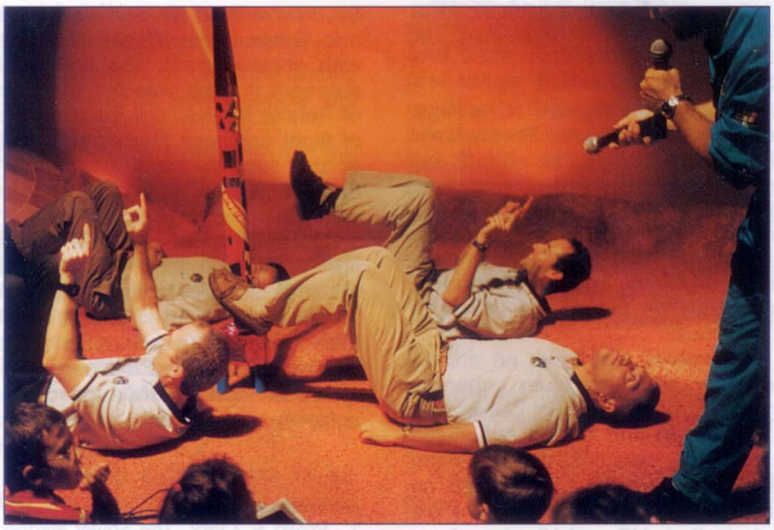
Spare Rocket

Sir, When you drive from the Visitor Center at the Kennedy Space Center to Port Canaveral along the SR-3 driveway, you can see wrecks of old equipment from Cape Canaveral. There are reservoirs, frames and also a real rocket!

It is the Atlas-B launcher, which was for many years exhibited at the Cape Canaveral Air Force Space Museum. But the place of this rocket has now been taken by another space launcher, the Blue Scout. Because an Atlas-E is exhibited at the Cape Canaveral Air Force Space Museum, the above-mentioned Atlas-B was eliminated from the exhibition.

TOMAS PRIBYL
Czech Republic

Charles Precourt, Edward Lu, Jean-Francois Clervoy and Carlos Noriega (from left) show how they were positioned in the Shuttle during their ascent to orbit. TON VAN ROOIJ



Afghan Cosmonauts

Sir, I write further to the article by Bert Vis in *Spaceflight* (Vol. 39, No. 11, November 1997, p.387) and the one by myself (Vol. 37, No. 1, January 1995, p.13) on the selection of Colonel Abdul Ahad Mohmand.

The following eight candidates were whittled down to two (Mohmand and Dauran) and not as previously thought (Gordon R. Hooper, *The Soviet Cosmonaut Team*, 1990):

Akajan	Air Force Colonel
Mohammed Dauran	Air Force Colonel
Mohammed Jahed	Civil Airline Pilot
Amir Khan	
Khial Mohammed	
Abdul Mohmand	Air Force Captain
Serajodin (Deceased)	
Shere Zamin	Air Force Major

Colonel Mohmand was adamant that he was always the prime candidate for the Soviet-Afghan mission, as he was younger and fitter than Dauran. He explained that when Russia invaded Afghanistan in 1980 the Soviet-backed Tajik regime persecuted his tribe the Pushtuns. When Mikhail Gorbachov became President, he attempted to ensure that the choice of finalists was between a Tajik and Pushtun.

However the Tajik media spread the news that Dauran was the first choice and, following his untimely case of appendicitis, had to settle for back-up status. Mohmand also stated that Dauran was never completely fit to fly and under more fair conditions would never have made the last two. However as has been the case in previous Intercosmos flights Dauran exerted his higher rank and influence in the Military and Government to make the final two candidates. Consequently there seemed to be a little more than just friendly rivalry between the two finalists.

In the name Abdul Ahad Sarvar Mohmand, the Sarvar is his Father's first name.

NEIL DA COSTA
London, UK

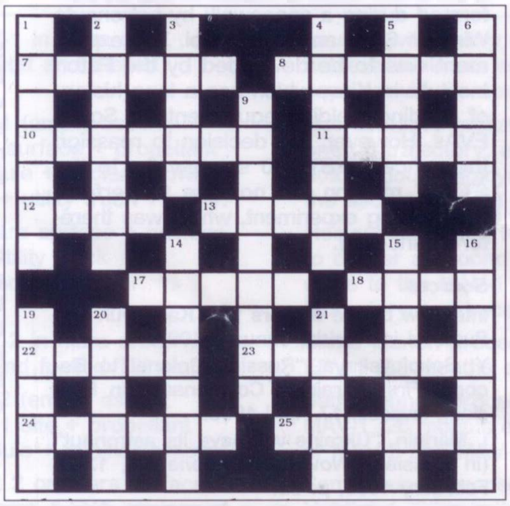
Spaceflight Crossword

No. 52

ACROSS
7. Elevated
8. Power generator
10. Manned space vehicle
11. Relieved
12. Horizontal
13. Intended
17. Oscillations
18. Lunar 'sea'
22. Joined together, as SRBs with ET
23. Regular procedure
24. European launch vehicle
25. Minimum

DOWN
1. Squeezed
2. Wrongly applied
3. Trials
4. Receives or transmits radio waves
5. European space telescope under development (acronym)
6. Prepared
9. Data relay device by radio link
14. Touch-down
15. Space probe of the 1960s and 1970s
16. Discovers
19. Sticky mark
20. Discoloration
21. Former Director General of ESA, now Chairman of Arianespace

Solution will appear in the January issue.



Solution to Crossword No.51.
ACROSS: 7. Spiral; 8. Galaxy; 10. Exhaust; 11. Solar; 12. Iced; 13. Being; 17. Venus; 18. GSFC; 22. Ozone; 23. Trapper; 24. Motion; 25. Gemini.
DOWN: 1. Asterix; 2. Fighter; 3. Value; 4. Cassini; 5. Tails; 6. Hydra; 9. Attenuate; 14. Develop; 15. Aseptic; 16. Scorpio; 19. Roams; 20. Route; 21. Bases.

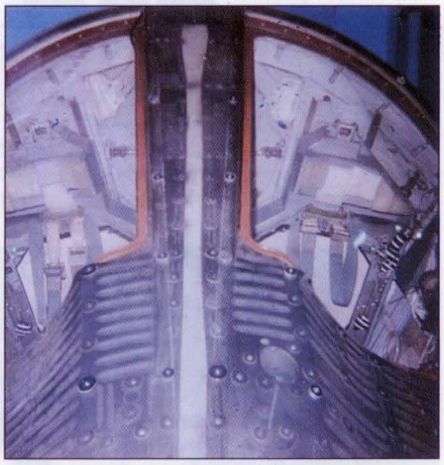
MOL/Gemini Vehicle

A port side view of the Gemini spacecraft taken at the Air Force Museum, Wright-Patterson Air Force Base, Ohio, USA in 1984. KEVIN COULOMBE

Sir, In 1993, *Spaceflight* published correspondence regarding the USAF Manned Orbiting Laboratory (MOL) and the Gemini space vehicle. A letter of mine was published regarding a MOL/Gemini vehicle that I saw in 1984 at the Wright-Patterson Air Force museum, Ohio, USA.

I have since located pictures that I took of the Gemini during my 1984 visit. On close inspection you can see the access hatch fitted to the aft bulkhead which provides access to the MOL.

A museum staff member that I have corresponded with says that the Gemini space vehicle in their collection did not fly, but they lack documentation for it. Inspection of the pictures indicates the lack of the aerodynamic scorching to be expected of a flown vehicle. This would lead me to believe that the Gemini is an engi-



A view through the left and right hatches. Visible are the left and right ejection seats and the hatch for access to the manned orbiting laboratories. KEVIN COULOMBE

A view through the left hatch. Visible are the left ejection seat, the space suit hoses and the hatch for access to the manned orbiting laboratory. KEVEN COULOMBE

neering prototype or test article that found its way to the museum following MOL termination in 1969. However, since the vehicle lacks its nose cap, this may be the Gemini-6 space vehicle, which was turned over to the Air Force for the MOL project and partially remanufactured. Further inquiries are pending.

If this Gemini were a MOL vehicle, it would be interesting to learn if a lab prototype or test article were actually constructed. The USAF had been actively procuring support equipment, such as pressure suits, up until programme termination. If a former employee of McDonnell Douglas is a BIS member perhaps they can open some more doors on the MOL project.

Finally, it is interesting to note that at the time of MOL development, Titan IIIs were "...designed and produced...specially certified as being suitable for inclusion in a manned flight system." The Titan III is the only man-rated booster that never fulfilled this role.

KEVIN G. COULOMBE
Washington State, USA

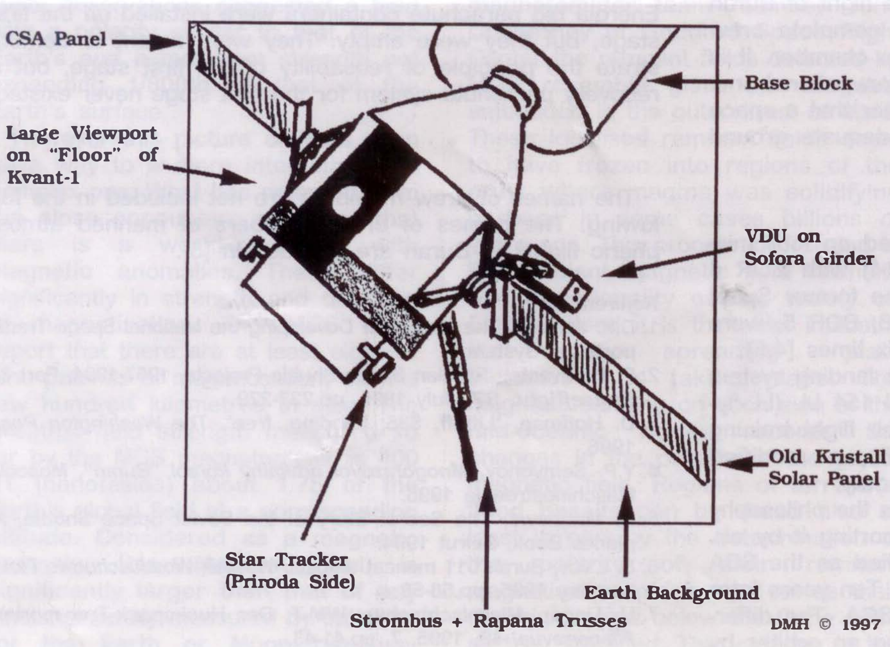
Mir Collision Mystery

Sir, Please find enclosed a sketch that I made upon seeing Channel 4 News show a recording of the view from the docking camera on Progress m-34 immediately before it collided with Mir on 25 June.

As you will see, the spacecraft was not approaching along the axis, so it was not in the process of attempting to dock with the port on the rear of the station when it strayed too close and collided. Having watched the collision, it is clear that the ferry pitched as it closed in, and the damage to the Spektr module was caused when the ferry backed into that module; it was not caused, as reported in the press at the time, by the spacecraft's nose during a head-on collision. The question is: Why was Progress M-34 manoeuvring in this position?

D.M. HARLAND, FBIS
Glasgow, UK

Progress M-34 Docking Camera View of Mir just before the Moment of Impact on 25 June 1997.



Space Shuttle and Buran Orbiters

An Overview of Tests and Flights of all Space Shuttles and Buran Orbiters to the End of 1996

BY THOMAS MAROLD
Jena, Germany

Orbiter Numbering Systems

All Space Shuttle orbiters with a leading 0 are test orbiters (MPTA 098 and STA 099). Flight orbiters have a leading 1 in their vehicle number (OV 101 - 105). Three orbiter-like vehicles exist without a number [1]:

- A full-scale mockup minus the left wing at the manufacturing company at Downey, California.
- A crew training mockup consisting of crew module and mid fuselage in building 9A at JSC.
- "Pathfinder", a transport test mockup, built by MSFC, now in a display at MSFC.

The numbering system of Buran airframes is not clear. Every test airframe has a number from 001 to 015 [2], but how many airframes exist and how the flight vehicles are included in this system is not clear.

Test vehicles are understood to have numbers beginning with 201, while flight vehicles begin with 101.

Ground Testing

Because Space Shuttle testing included key hardware elements and verifying analytical models, only two test airframes, a test tail section and some elements (upper forward fuselage, OMS pod, vertical stabiliser, nose cap) were built [1]. One of the test airframes was later converted into a flight qualified vehicle.

Buran was a copy of the Space Shuttle [3], but with different systems. But to understand, how the Space Shuttle works, the Soviets had to do all the testing themselves. Six test airframes were built to prepare for the flight of Buran [4]. For testing the life support system a complete crew module was also built, located in a vacuum chamber. It is obvious that the testing philosophy was a conventional one. The Soviets had learned from the N-1 disaster that a space programme can fail completely due to inadequate ground testing.

Flight Testing

The heat shield of Buran was flight tested on four missions (Cosmos 1374, 1445, 1517 and 1614) with BOR 4 mockups which resembled the shape of the former Spiral orbiter. Buran mockups on the scale of 1:8, BOR 5, were flown on ballistic trajectories to 7.3 km/s six times [4,5].

Crew training and testing of the automatic landing system in the Buran program was done with a TU 154 LL (LL-flying laboratory). Space Shuttle crews do their flight training with the STA (Shuttle Training Aircraft), a modified Gulfstream, of which three aircraft are on duty.

Completely different in both programs was the philosophy for flight testing the real orbiter and transporting it by air. In the USA, a used Boeing 747 was modified as the SCA (Shuttle Carrier Aircraft) for both purposes. Ten years later a second 747 was modified as a backup SCA. The difference between flight testing and transporting an orbiter by the SCA was a modification of the forward support strut to a cant angle of six degrees for flight testing and three degrees for transporting [1].

For flight testing Buran, a test vehicle was modified with four jet engines. This aircraft could take-off under its own power and did not need a carrier aircraft. On the Space Shuttle, jet engines on the orbiter were removed in the project phase. In the Buran program, most of test orbiters, BOR 5 and flight orbiters 1 and may be 2 had two jet engines installed on both sides of the vertical stabiliser (see photos in [4] and in this article). Later in the programme these engines were removed.

Transporting a Buran orbiter was a problem. From the plant in Moscow Tuchino to Shukowsky (Ramenskoye) transport was by barge on the Moskwa river [6]. For air transport from there to Baikonur there existed a fleet of two modified Myasitchev 3 M which were named 3M-T [4] or WM-T "Atlant". This modified bomber was also used for transporting the Energia LOX and LH_2 tanks to Baikonur [7]. It had a transport capability of only 45 metric tons. Transporting a Buran orbiter was possible only for the airframe without rudder, crew module and ODU (a combined OMS and RCS) [4]. At Baikonur, in MIK 254 (which is comparable to the OPF) the orbiter had to be completed. Further means of transportation by air was impossible until late in the programme when the An 225 "Mrya" was ready.

Comparing the launch configurations of the STS and Energia/Buran, it is obvious, that the STS is more reusable, than Energia/Buran. The size of the Energia second stage engines 11 D 122 prevents use of propulsion on the orbiter itself. The Energia second stage is comparable to the STS-external tank and burns on re-entry. On both flights of Energia big parachute containers were installed on the first stage, but they were empty. They were meant to demonstrate the principle of reusability of the first stage, but a recovery parachute system for the first stage never existed.

* * *

The names of crew members are not included in the following. The names of crew members of manned atmospheric flights of Buran are included in [5].

References

1. D.R. Jenkins, The History of Developing the National Space Transportation System.
2. P. Pesavento, 'Russian Space Shuttle Projects, 1957-1994; Part 3'. *Spaceflight*, 37, July 1995, pp.227-229.
3. D. Hoffman, 'Liftoff, $35; Landing, free', *The Washington Post*, 1996.
4. Y.P. Semyonov, *Mnogorazovoi orbitalny korabl "Buran"*, Moscow Maschinostroenie 1995.
5. H. Matthews, The Secret Story of the Soviet Space Shuttle, X-planes Book, Beirut 1994.
6. S. L'vov, Buran 011 menaet amplua, *Westnik Wosduschnowo Flota*, January 1995, pp.58-59.
7. U. Unger, Mjassischtschew WM-T, Der Huckepack-Transporter. *Fliegerrevue*, 43, 1995, 7, pp.41-43.

Space Shuttle Orbiter Activities

Main Propulsion Test Article MPTA-098

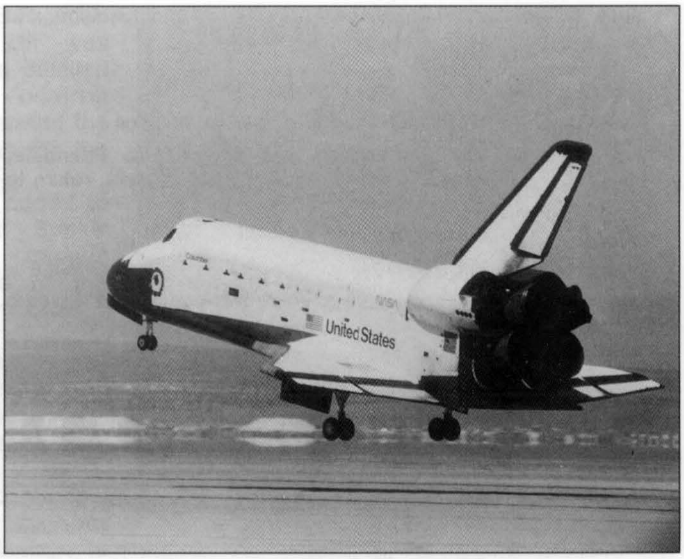
24 Jun 75	Start Assembly
27 May 77	Complete Assembly (Status: Orbiter tail section and structure which simulated the mid fuselage)
24 Jun 77	Moved to NSTL, mated with MPTA-ET, prototype SSME
21 Apr 78	First static firing, non flight rated SSME
2 Jul 79	Tests with flight qualified SSME; major structural damage by engine 2002
17 Jan 81	Tests with SSME's from OV 102
1989-90	Essex-Corporation/Boeing used the thrust structure from MPTA-098 for assembling an engineering model of Shuttle-C at MSFC

Static Test Article STA-099/OV-099 "Challenger"

21 Nov 75	Start Assembly
14 Feb 78	Rollout to structural test rig in palmdale (Status: complete airframe without equipment and heatshield)
15 Mar 78	Begin Testing
7 Nov 79	Testing Completed, Conversion into OV-099 begins
30 Jun 82	Rollout as OV-099 "Challenger"
19 Dec 82	Flight readiness firing
4-9 Apr 83	1. Flight: STS 6, manned (4), EVA, TDRS-1, Landing Edwards
18-24 Jun 83	2. Flight: STS 7, manned (5), Anik C-2, Palapa B-1, SPAS-01, Landing Edwards
30 Aug-5 Sep 83	3. Flight: STS 8, manned (5), Insat 1B, FPTA, Landing Edwards
3-11 Feb 84	4. Flight: 41 B, manned (5), EVA with MMU, Westar 6, Palapa B-2, SPAS-01 (not released), Landing KSC
6-13 Apr 84	5. Flight: 41 C, manned (5), EVA, LDEF, SMM repair, Landing Edwards
5-13 Oct 84	6. Flight: 41 G, manned (7), EVA, ERBS, Landing KSC
29 Apr-6 May 85	7. Flight: 51 B, manned (7), Spacelab 3, GLOMR (not released), Landing Edwards
12 Jul 85	Abort on Pad T-3s
29 Jul-6 Aug 85	8. Flight: 51 F, Abort to Orbit, manned (7), Spacelab 2, Landing Edwards
30 Oct-6 Nov 85	9. Flight: 61 A, manned (8), Spacelab D-1, Landing Edwards
28 Jan 86	10. Flight: 51 L, manned (7), first launch from Pad 39 B, vehicle destroyed at + 73 s by ET explosion, SRB's destroyed at + 110 s by RSO, Death of crew at + 4 min by sea impact of crew module
next months	30 % of wreckage recovered for accident analysis
	Remains of OV-099 stowed at two Minuteman III-silos at LC 31 at Cape Canaveral Air Force Station

Orbiter Vehicle OV-101 "Enterprise"

4 Jun 74	Start Assembly as OV 101 "Constitution"
12 Mar 75	Complete Assembly (Status: Airframe with systems for atmospheric flight, ejection seats, DFI package, without heatshield and any rocket motors)
summer 76	Horizontal Ground Vibration Test (HGVT), 0.5-50 Hz:
	- HGVT soft mount (simulating free flight, payload bay doors open and closed)
	- HGVT rigid mount (simulating ascent configuration)



Columbia returns to Earth. Completing the first full test of the Space Transportation System (STS-1), the Orbiter Columbia is seen here on its final approach prior to landing on Rogers Drylake Runway 23 at NASA's Dryden Flight Research Center, Edwards, California. For this first flight the Columbia was flown by Astronauts John Young, Commander, and Pilot Robert Crippen. NASA

17 Sep 76	Rollout as OV 101 "Enterprise"

Approach and Landing Tests (ALT):

8 Feb 77	Mated to B 747 (N 905 NA) at Edwards, weight, balance and vibration tests (tailcone on)
15 Feb 77	3 taxi tests, 76 kt, 120 kt, 137 kt (last 2 nose gear lifted)
18 Feb 77	ALT-IC 1 First Flight on B 747 Inactive Captive, flaps-gear and stability tests
22 Feb 77	ALT-IC 2, flutter tests
25 Feb 77	ALT-IC 3, flutter-and stability tests, engine out test
28 Feb 77	ALT-IC 4, pre free flight, touch and go
2 Mar 77	ALT-IC 5, two pre free flights, full breaking at landing
18 Jun 77	ALT-CA 1, Active Captive, manned (2), aerosurfaces and split-rudder braking test
28 Jun 77	ALT-CA 2, manned (2), flutter-and speed brake tests, simulated separating manoeuvre, microwave landing system (MSBLS)
26 Jul 77	ALT-CA 3, manned (2), simulated separating manoeuvre, TACAN, MSBLS, OV-101 gear down after landing
12 Aug 77	ALT-FF 1, free flight (tailcone on), manned (2), two 90° turns flown, ABS and nose gear steering
13 Sep 77	ALT-FF 2, manned (2), turns with 55° Bank angle, speed break manoeuvres
23 Sep 77	ALT-FF 3, manned (2), auto land test with MSBLS, hard break
12 Oct 77	ALT-FF 4, first tailcone off flight, manned (2), no traffic pattern, flight straight away
26 Oct 77	ALT-FF 5, tailcone off, manned (2), landing on concrete runway
15-18 Nov 77	Four test flights in ferry configuration: Tailcone on, Orbiter deactivated, replaced forward attachment strut on B 747 (now cant angle 3° instead of 6°)
13 Mar 78	To MSFC, start of Mated Vertical Ground Vibration Tests
to 15 Sep 78	- OV 101 with ET (LOX tank filled with water) and inert SRB's
to 5 Dec 78	- OV 101 with ET (LOX tank partially filled with water)
to 26 Feb 79	- OV 101 with ET (LOX tank partially filled) and empty SRB's

Decision, instead of OV 101 modify STA 099 as an flight Orbiter,

because of structural weakness of OV 101 in mid fuselage and wings.

10 Apr 79	To KSC, check facilities at LC 39
1 May-23 Jul 79	on Launch Pad 39 A, pad verification
16 Aug-30 Oct 79	Via Vandenberg and Edwards to Palmdale, remove devices used for other Orbiters, return to Edwards 6 Sep 81
May-Jun 83	Europe tour and Paris Air Show
5 Apr 84	Via Mobile/Ala to World's Fair in New Orleans
late 84-85	To Vandenberg AFB, verification of Launch Complex SLC 6
24 May 85	To Edwards
20 Sep 85	On display in KSC near VAB
18 Nov 85	To National Air and Space museum at Dulles Airport Washington DC (stowed in hangar until now)
8 Jun 87	Slow test of a landing arresting barrier

OV 102 "Columbia"

4 Jun 74	Start Assembly
8 Mar 79	Rollout (Status: with ejection seats, not completely ready, completion in KSC Orbiter processing facility)
20 Feb 81	Flight readiness firing on Launch Pad 39 A KSC
12-14 Apr 81	1. Flight: STS 1, manned (2), LC 39 A, first flight of a space shuttle in orbit, DFI package, landing Edwards
12-14 Nov 81	2. Flight: STS 2, manned (2), DFI, OSTA 1 pallet, landing Edwards
22-30 Mar 82	3. Flight: STS 3, manned (2), DFI, landing White Sands
27 Jun-4 Jul 82	4. Flight: STS 4, manned (2), DFI, last test flight, DoD-Payload, landing Edwards concrete runway
11-16 Nov 82	5. Flight: STS 5, manned (4) ejection seats deactivated, SBS1, Anik C3, landing Edwards
28 Nov-9 Dec 83	6. Flight: STS 9, manned (6), Spacelab 1, landing Edwards
12-18 Jan 86	7. Flight: 61 C, manned (7), Satcom K1, landing Edwards
8-13 Aug 89	8. Flight: STS 28, manned (5), classified DoD-mission, Landing Edwards
9-20 Jan 90	9. Flight: STS 32, manned (5), Leasat, return of LDEF, landing Edwards
2-11 Dec 90	10. Flight: STS 35, manned (7), Astro 1, landing Edwards
5-14 Jun 91	11. Flight: STS 40, manned (7), Spacelab Space Life Sciences 1 (SLS 1), landing Edwards
25 Jun-9 Jul 92	12. Flight: STS 50, manned (7), Spacelab Microgravity Laboratory USML 1, landing KSC
22 Oct-1 Nov 92	13. Flight: STS 52, manned (6), Lageos 2, landing KSC
22 Mar 93	Abort on Pad T-3s
26 Apr-6 May 93	14. Flight: STS 55, manned (7), Spacelab D2, landing Edwards
18 Oct-1 Nov 93	15. Flight: STS 58, manned (7), Spacelab SLS 2, landing Edwards
4-18 Mar 94	16. Flight: STS 62, manned (5), OAST 2, USMP 2, landing KSC
8-23 Jun 94	17. Flight: STS 65, manned (7), Spacelab IML 2, landing KSC
20 Oct-5 Nov 95	18. Flight: STS 73, manned (7), Spacelab USML 2, landing KSC
22 Feb-9 Mar 96	19. Flight: STS 75, manned (7), USMP 3, TSS 1R, landing KSC
20 Jun-7 Jul 96	20. Flight: STS 78, manned (7), LMS 1 (Spacelab), landing KSC
19 Nov-7 Dec 96	21. Flight: STS 80, manned (6), WSF 3, Orpheus-SPAS, landing KSC

OV 103 "Discovery"

28 Jun 76	Start Assembly
16 Oct 83	Rollout
2 Jun 84	Flight Readiness Firing
26 Jun 84	Abort on Pad T-3s
30 Aug-5 Sep 84	1. Flight: 41 D, manned (6), Leasat 1, Syncom IV-1, Telesat 1, Solar generator, landing Edwards
8-16 Nov 84	2. Flight, 51 A, manned (5), Anik D2, Leasat 1, return of: Palapa B2 and Westar 6 by EVA, landing KSC
24-27 Jan 85	3. Flight: 51 C, manned (5), classified DoD-mission (Signit 1), landing KSC
12-19 Apr 85	4. Flight: 51 D, manned (7), Telesat 1, Syncom IV-3, EVA, landing KSC
17-24 Jun 85	5. Flight: 51 G, manned (7), Morelos A, Arabsat 1, Telstar 3D, Spartan 1 (and return), landing Edwards
27 Aug-3 Sep 85	6. Flight: 51 I, manned (5), Aussat 1, ASC 1, Syncom IV-4, repair Syncom IV-3 by EVA, landing Edwards
10 Aug 88	Flight readiness firing LC 39 B
29 Sep-3 Oct 88	7. Flight: STS 26, manned (5), TDRS 3, landing Edwards
13-18 Mar 89	8. Flight: STS 29, manned (5), TDRS 4, landing Edwards
23-28 Nov 89	9. Flight: STS 33, manned (5), classified DoD-mission, landing Edwards
24-29 Apr 90	10. Flight: STS 31, manned (5), HST, landing Edwards
6-10 Oct 90	11. Flight: STS 41, manned (5), Ulysses, landing Edwards
28 Apr-6 May 91	12. Flight: STS 39, manned (7), SPAS 2-01, landing KSC
13-18 Sep 91	13. Flight: STS 48, manned (5), UARS, landing Edwards
22-30 Jan 92	14. Flight: STS 42, manned (7), Spacelab IML 01, landing Edwards
2-9 Dec 92	15. Flight: STS 53, manned (5), classified DoD-mission, landing KSC
8-17 Apr 93	16. Flight: STS 56, manned (5), ATLAS 2, Spartan, landing KSC
13 Aug 93	Abort on Pad T-3s
12-22 Sep 93	17. Flight: STS 51, manned (5), ACTS, Astro-SPAS, EVA, landing KSC
3-11 Feb 94	18. Flight: STS 60, manned (6), Spacehab 2, Wake Shield, Bremsat, landing KSC
9-21 Sep 94	19. Flight: STS 64, manned (6), Spartan 201, SAFER-EVA, LITE, landing Edwards
3-11 Feb 95	20. Flight: STS 63, manned (6), Spartan, Spacehab, MIR-Rendezvous, EVA, landing KSC
13-22 Jul 95	21. Flight: STS 70, manned (5), TDRS-G, landing KSC

OV 104 "Atlantis"

3 Mar 80	Start structural assembly
6 Mar 85	Rollout
5 Sep 85	Flight readiness firing
3-7 Oct 85	1. Flight: 51 J, manned (5), classified DoD-mission (two DSCS 3 satellites), landing Edwards
27 Nov-3 Dec 85	2. Flight: 61 B, manned (7), Morelos B, Aussat 2, Satcom KU 2, EVA with ACCES and EASE, landing Edwards
2-7 Dec 88	3. Flight: STS 27, manned (5), DoD-mission, Lacrosse, landing Edwards
4-8 May 89	4. Flight: STS 30, manned (5), Magellan, landing Edwards
18-23 Oct 89	5. Flight: STS 34, manned (5), Galileo, landing

	Edwards
28 Feb-4 Mar 90	6. Flight: STS 36, manned (5), DoD-mission, KH 12, landing Edwards
16-21 Nov 90	7. Flight: STS 38, manned (5), DoD mission, Magnum 3 (?), landing KSC
5-11 Apr 91	8. Flight: STS 37, manned (5), GRO, EVA, MIR-Approach 200 km, landing Edwards
2-11 Aug 91	9. Flight: STS 43, manned (5), TDRS 5, landing KSC
25 Nov-1 Dec 91	10. Flight: STS 44, manned (6), DoD-mission, DSP-16, landing Edwards
24 Mar-2 Apr 92	11. Flight: STS 45, manned (7), Atlas 01, landing KSC
31 Jul-8 Aug 92	12. Flight: STS 46, manned (7), Eureca, TSS-1, landing KSC
3-14 Nov 94	13. Flight: STS 66, manned (6), Atlas 3, Christa SPAS, landing Edwards
27 Jun-7 Jul 95	14. Flight: STS 71, manned (7/8), Spacelab, MIR-Docking, landing KSC
12-20 Nov 95	15. Flight: STS 74, manned (5), MIR-Docking, landing KSC
22-31 Mar 96	16. Flight: STS 76, manned (6), MIR-Docking, EVA, landing Edwards
16-26 Sep 96	17. Flight: STS 79, manned (6), MIR-Docking, Spacehab (2), landing KSC

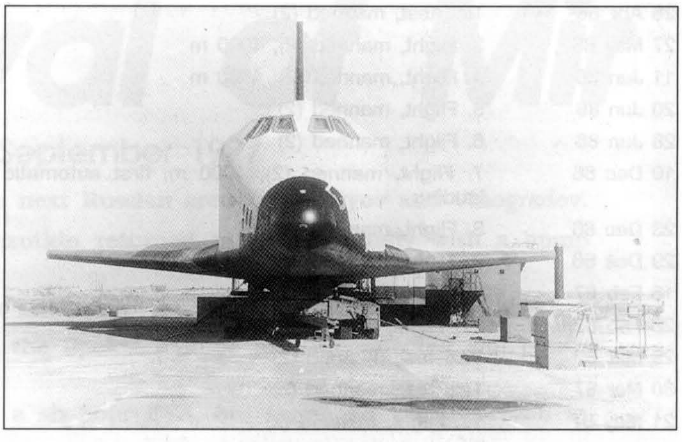
OV 105 "Endeavour"

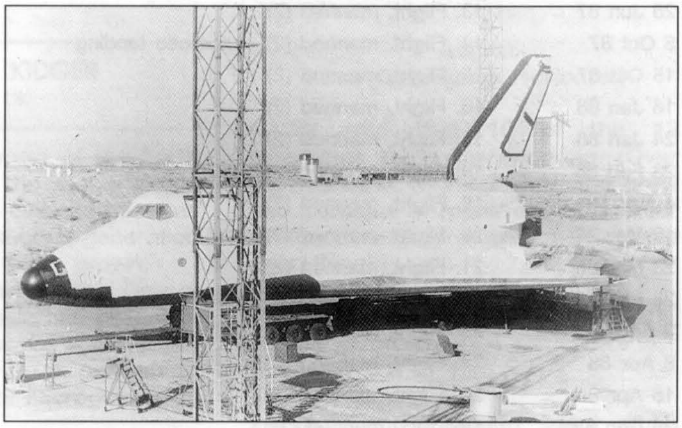
15 Feb 82	Start structural assembly as set of structural spares
15 Apr 91	Rollout
6 Apr 92	Flight readiness firing
8-16 May 92	1. Flight: STS 49, manned (7), Repair of Intelsat IV F3 by EVA, landing Edwards
12-20 Sep 92	2. Flight: STS 47, manned (7), Spacelab J, landing KSC
13-19 Jan 93	3. Flight: STS 54, manned (5), TDRS 6, EVA, landing KSC
21 Jun-1 Jul 93	4. Flight: STS 57, manned (6), Spacehab, Eureca-return, landing KSC
2-13 Dec 93	5. Flight: STS 61, manned (7), HST-repair, EVA, landing KSC
9-20 Apr 94	6. Flight: STS 59, manned (6), SRL 1 (SIR C), MIR-radiocontact, landing Edwards
18 Aug 94	Abort on pad T-2s
30 Sep-11 Oct 94	7. Flight: STS 68, manned (6), SRL 2, landing Edwards
2-18 Mar 95	8. Flight: STS 67, manned (7), Astro 2, landing Edwards
7-18 Sep 95	9. Flight: STS 69, manned (5), Spartan 201-03, Wakeshield, EVA, landing KSC
11-20 Jan 96	10. Flight: STS 72, manned (6), SFU-return, OAST, EVA, landing KSC
19-29 May 96	11. Flight: STS 77, manned (6), Spacehab 4, Spartan 207, landing KSC

Buran Orbiter Activities

OK-M No. 001

also named:	BTS-01, OK-ML1 (OK means Orbitalny Korabl = Orbital Craft)
Status:	Airframe, weight-volume model of internal equipment, equipped with two mock up TL-engines (later removed)
	static tests
	horizontal dynamic tests soft mounted horizontal dynamic tests rigid mounted
Mar 83	Aircraft transport tests on 3M-T from Shukowski (Ramenskoje) according to [5] landing accident
	Flown on 3M-T to Baikonur (ferry flights as cargo 0GT: without rudder, crew module and ODU (OMS and RCS), with tailcone, cargo limited to 45 metric tons)
	Vertical Ground vibration tests in Baikonur (together with Energia launcher) Tests in Echo-free chamber in MIK 254
until 94	Stowed in MIK 254 (MIK = Assembly and Test Building)
1995	Located in free air at ODU-firing place near MIK 254 in Baikonur





Until 1994, the full-scale Buran BTS-01 was stored in the Assembly and Test Building (MIK) No. 254 at Baikonur. In 1995 it was moved into the open air near MIK 254 to make room for the prelaunch preparation and testing of the Priroda module for Mir.
V. NIKOLAYEV © February 1995 (supplied courtesy of T. Varfolomeyev)

OK-GLI No. 002

Orbitalny Korabl-Gorizontalnye Letnye Izbytaniya (Orbital Craft-Horizontal Flight Testing)

also named:	OK-ML 2, BTS-02
Status:	Airframe equipped for atmospheric flights, K 36 ejection seats, 4 Lyulka TL-engines AL-31, longer nose gear. Registered as aircraft: CCCP 350 002

All test flights are from Shukowski (Ramenskoje). According to [4] 24 flights were done, 19 of them with automatic approach until 10...20 m altitude and following second traffic pattern and two touch and go-landings. Fifteen flights ended in full automatic landings (until stop on runway).

dynamic tests (horizontal position)

29 Dec 84	Low speed taxi test, manned (2)
2 Aug 85	Taxi test, manned (2)
5 Oct 85	Taxi test, manned (2)
15 Oct 85	Taxi test, manned (2)
10 Nov 85	1. Flight, manned (2), 1500 m
15 Nov 85	Taxi test, manned (2)
3 Jan 86	2. Flight: manned (2), 3000 m

26 Apr 86	Taxi test, manned (2)
27 May 86	3. Flight, manned (2), 4000 m
11 Jun 86	4. Flight, manned (2), 4000 m
20 Jun 86	5. Flight, manned (2)
28 Jun 86	6. Flight, manned (2)
10 Dec 86	7. Flight, manned (2), 4000 m, first automatic landing
23 Dec 86	8. Flight, manned (2)
29 Dec 86	9. Flight, manned (2)
16 Feb 87	10. Flight, manned (2)
25 Feb 87	11. Flight, manned (2)
29 Mar 87	Taxi test, manned (2)
30 Mar 87	Taxi test, manned (2)
21 May 87	12. Flight, manned (2)
25 Jun 87	13. Flight, manned (2)
5 Oct 87	14. Flight, manned (2), automatic landing
15 Oct 87	15. Flight, manned (2)
16 Jan 88	16. Flight, manned (2)
24 Jan 88	17. Flight, manned (2)
23 Feb 88	18. Flight, manned (2)
4 Mar 88	19. Flight, manned (2)
12 Mar 88	20. Flight, manned (2)
23 Mar 88	21. Flight, manned (2)
28 Mar 88	22. Flight, manned (2)
2 Apr 88	23. Flight, manned (2)
8 Apr 88	24. Flight, manned (2)
15 Apr 88	25. Flight, manned (2)
28 Dec 88	Taxi test, manned (2)
1992	Vehicle first shown to the public (in static display)
1995	Located in Gromov-Flight Test Institute in Shukowski

OK-KS No. 003

Orbitalny Korabl-Kompleksny Stend (Complex Stand)

Status: Airframe with all on board systems working, for static use only

System integration

Complex electric testing:

- electromagnetic interactions
- workability under all on board voltage condition (from max to min)
- current usage, testing means against overloads
- right polarity of all actors
- tests of caution and warning system
- mathematical models for ground testing
- telemetry analysis
- specialist training for ground and prelaunch operations

Located at NPO Energia in Kaliningrad (northeast of Moscow)

OK-MT No. 004 "Baikal"

Orbitalny Korabl-Maket Teknologicheski (Technological model)

Status: Engineering mockup with weight-volume model of internal equipment, equipped with two mock up TL-engines (later removed)

Production and engineering work flow, docking with Mir station

Static tests

Ferry flight to Baikonur on 3M-T (tests of transport equipment)

Fuelling tests

Post landing operations including crew recovery

Pre-launch check out procedures and launch operations (also as training of launch crew) on launch pad: Place 110 left

until 94	Stowed in MIK 254
1995	Stowed in technical position (fuelling hangar) at launch complex 110

OK-TVA No. 005

Orbitalny Korabl-Teplo Vibroprotchnotnych Akusticheskych Izbytaniya (Thermo-Vibration and acoustic tests)

Status: set of structural segments (because of volume limit of test chamber)

- forward fuselage
- mid fuselage
- aft fuselage
- wing

'Early Communications Satellites' Competition

This month's competition centres on the beginnings of communications satellites and some of the 'firsts' that were achieved in the 1960s and 1970s.

Prize: The first correct entry to be opened after the closing date of 18 December 1997 will receive a copy of the book:

'Beyond the Ionosphere: Fifty Years of Satellite Communications'
Edited by Andrew J. Butrica

This book (of 317 pages in hardback) describes the first attempts to achieve long-distance radio communication by going beyond the ionosphere and the evolution that has led to today's satellite communication organisations. The book was published in 1997 in the NASA History Series by NASA History Office, Washington DC 20546 and is available from the US Superintendent of Documents, PO Box 371954, Pittsburgh, PA 15250-7954. ISBN 0-16-049054-5.

To Enter: Fit the following names: Anik A1; Courier 1B; Echo 1; Intelsat 1; Marisat 1; Molniya 1; Relay 1; Telstar 1, to satellites that were the first of their kind:

1. The first successful passive communications satellite. ....
2. The first active communications satellite with message store-and-forward capability. ....
3. The first communications satellite to offer transatlantic TV. ....
4. The first communications satellite to transmit TV worldwide. ....
5. The first Soviet communications satellite. ....
6. The first commercial communications satellite. ....
7. The first Canadian domestic geostationary satellite. ....
8. The first communications satellite to provide commercial mobile satellite services. ....

Post to:
The British Interplanetary Society
27/29 South Lambeth Road,
London SW8 1SZ, England

To arrive by first delivery on 18 December 1997.

Entries may be submitted on a photocopy or otherwise written out in a clear and unambiguous form.

No multiple entries please.

Title/
Name ....

Address ....

....

....

....

- vertical stabiliser
- elevon
- body flap
- nose cap
- wing leading edge

Static tests in thermo chamber (-150 ... 1500 deg. centigrade)

Vibration tests (test stand until 200 kN, up to 2000 Hz)

Acoustic tests in test chamber (up to 162 dB, 1250 kW, 50... 2000 Hz)

OK-TVI No. 006

Orbitalny Korabl-Teplovakuumnych Izbytaniya (Thermo-Vakuum tests)

Status: set of structural segments with thermal equivalents of on board equipment and working thermal control system:

- forward fuselage with crew module
- mid fuselage
- aft fuselage
- vertical stabiliser
- radiator panels

Static thermovacuum tests (until 10-4 Pa, solar and earth radiation, liquid nitrogen heat sink)

No. 011

Status: airframe without internal equipment

Static test article

21 Oct 93 Moved to Gorky Park in Moscow

95 Operated by Space-Earth enterprise, in conversion to an tourist attraction "Spaceflight simulator"

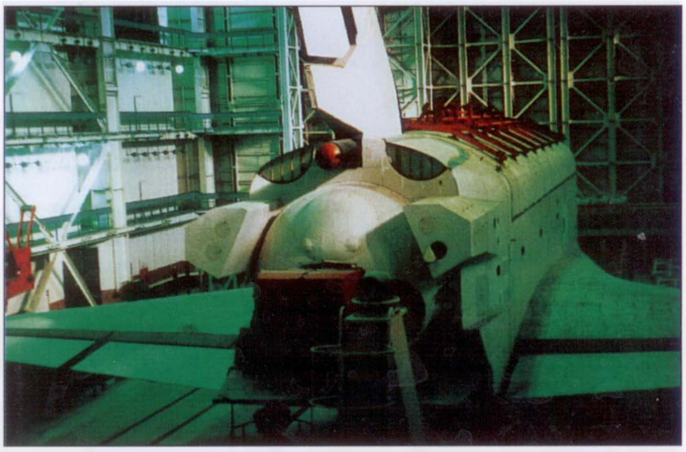
Jul 96 In operation as tourist attraction

No. 015

Status:	Set of structural fragments
	Thermovacuum Tests

OK 1K1 "Buran"

1981	In construction
1984	Rollout (NPO Molniya)
	Ferry Flight to Baikonur on 3M-T
15 Oct 87	End of completion, Status: ready for Spaceflight, only minimum life support systems (not ready for manned flight), no fuel cells
-15 Feb 88	Test station and echo-free chamber (MIK 254)
-25 Apr 88	Flight readiness firing of ODU (OMS and RCS) on ODU firing place
-9 May 88	Operations in Energia MIK, mating with Energia
-19 May 88	Operations in Energia MIK together with Energia, transport to LC 110 left
-19 Jun 88	Tests on launch pad 110 left
-29 Aug 88	Work on ODU (OMS and RCS)
-13 Sep 88	Mating with Energia, Tests in MIK, transport to fuelling hangar (technical position)
-10 Oct 88	Fuelling of Buran in fuelling building, transport to LC 110 left
-26 Oct 88	Launch preparations
-29 Oct 88	Count down, launch automatic cancelled at T-51 s, because of not rotating azimuth aligning platform from spacecraft
15 Nov 88	1. Flight: Launch from LC 110 left on Energia No. 1L, unmanned, 2 orbits, cargo: BDP (DFI package), Landing Baikonur at Landing Complex 251
May 89	Test flights on An 225 from Baikonur to Kiew (64 test flights)
Jun 89	Ferry Flight on An 225 to Paris Air Show (Return via Prague) detailed Inspection in Baikonur



Buran No. 004 in storage in the fuelling hangar in September 1995. The covered openings on either side of the vertical fin formerly accommodated the two jet engines.

92 ?	Retired from service as flight qualified vehicle
1995	Stowed in MIK 254 in Baikonur

OK 2K1

Status:	Ready for manned flight, with manipulator and Docking unit for Mir
1989	Already at Baikonur in a state of completion
1991	Test on LC 110
1994	Stowed in MIK 254
1995	Stowed in technical position (fuelling hangar) at launch complex 110

OK 3K1

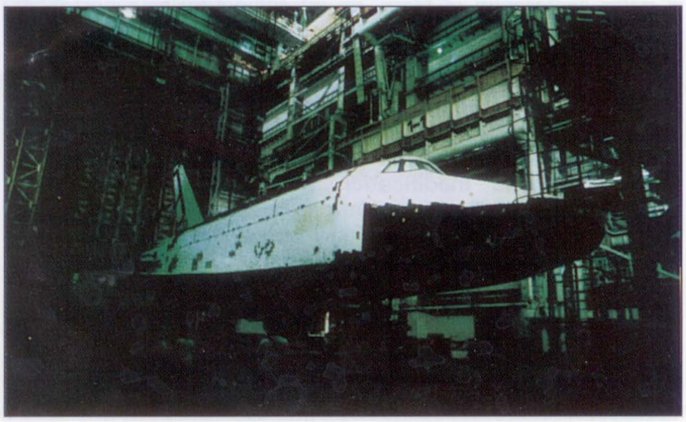
89-95	In construction at NPO Molnya

OK 4K1 and 5K1

According to programme planning, five flight vehicles should have been constructed. It is not clear up to now whether or not these vehicles exist. Maybe they exist as a set of structural fragments, which were not assembled, because the programme was stopped.

Buran 011 in Moscow's Gorky Park and still unpainted in September 1994.

OK 2K1 (Buran 2) in storage in the fuelling hangar (September 1995).



BOOK NOTICE INDEX FOR 1997

COMPUTER SOFTWARE

AUTHOR INDEX FOR 1997

SUBJECT INDEX FOR 1997

SOCIETY ANNOUNCEMENTS

Space Communications for a New Millennium

Thursday, 11 December 1997
to be held at
Scientific Societies Lecture Theatre,
New Burlington Place, London W1

(Co-sponsored by BNSC and Matra Marconi Space in collaboration with the BIS)

Outline Agenda

Morning Session

Space Communications:
A History and Background
M. Painter

Current Satellite Technologies
D. Robson,
Matra Marconi Space

Development of Earth Stations and Ground Terminals
TBA
ICO/INMARSAT

Future Satellite Systems and Technologies
E. Ashford
ESTEC

Afternoon Session

The Role of Satellites in Today's Global Information Infrastructure
TBA

The Provision of Satellite Services from Regulation to Commercial Applications
J. Davies
Dept Trade & Industry

Satellite Communications - Risks and Opportunities
TBA
Willis Corroon Inspace

Next Generation Satellite Services
M. Dillon
ESYS

New Satellite Services for the Next Millennium
Jon Wakeling
British Telecom

Cocktail Reception
Sponsored by
Matra Marconi Space
Cost: £30.00 members of BIS,
non members £50.00.
(Refreshments and Lunch included)
Registration forms are available from the Executive Secretary.
Please enclose a sae.

Small Satellites Symposium

(Sponsored by DERA in collaboration with the BIS and RAeS)

Wednesday 12 November 1997
09.30 am - 16.30 pm
to be held at
The Defence Evaluation and Research Agency, Farnborough, Hampshire

Provisional Programme

SESSION 1: Technology Needed by Small Satellites

Welcome and Introduction
Graham Davison, DERA

UoSAT - 12 Mini Satellite Mission
Prof. Martin Sweeting,
Surrey Satellite Technology Ltd

Lithium Batteries for Small Satellite Applications
Mike Slimm, AEA Technology

Bulk Fabrication for Microthrusters *via* Laser Processing Techniques
Henry Helvajian,
The Aerospace Corporation

Development of Project Specific Hardware for Small Satellites
Kim Ward, Space Innovations Ltd

SESSION 2: Tour of DERA Space Test Facilities and Ion Propulsion Laboratories

SESSION 3: The Use of Small Satellites for Proving New Technology

Overview of the ESA Small Satellites Programme

The ESA Project for On Board Autonomy (PROBA),

SAR Concepts
Dr Gordon Keyte, DERA

CCSDS Communication Standards for STRV-1c/d
Steve Foley, DERA

STRV-1c/d Programme
Commander Richard Blott, DERA

Cost: £30.00 members of BIS, RAeS and DERA staff, non members £50.00.
Refreshments and Lunch included. Places limited to 90 including 6 student places.
Registration forms are available from the Executive Secretary. Please enclose a sae.

SPECIAL MEETING
Christmas Get-Together

A Celebration of the 80th Birthday of Arthur C. Clarke
at the Society's HQ on 16 December 1997

6 - 8.30 pm

Join Mat Irvine as he toasts the 80th Birthday of Arthur after a short presentation and slide show about Arthur's work and a video message in response from Arthur in Sri Lanka.

This informal event is an opportunity for members to visit the Society and meet the Society's President, Mark Hempsell, along with members of its Council and Committees and other members.

Refreshment Buffet

For tickets, price £5 incl. refreshments, apply to the Executive Secretary,
The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ
enclosing a sae. Early application is advised.

LIBRARY and INFORMATION SERVICES

Library Opening Hours:

The Society's Library is open to members on the first Wednesday of each month (except August) between 5.30 and 7 pm when there is an evening lecture and between 1 and 4.30 pm when there is no evening lecture. Membership cards must be produced.

Spaceline:

For the latest space news and launch reports call 0891 770 794. Calls cost 50p per minute at all times.

World Wide Web Page:

Updated information on current activities appear on the BIS Homepage on WWW at the following address: http://freespace.virgin.net/bis.bis/Bis.htm

BIS on the WWW

To find out more about the BIS, visit the BIS homepage on the World Wide Web at:

http://freespace.virgin.net/bis.bis/Bis.htm

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Mr Pat Norris, FBIS
A 30 year space veteran, starting in the 1960s in the USA with space geodesy and the Apollo missions, then with ESA for 10 years and now in UK industry, where he is currently Chairman of the industry trade association, UKISC, and Manager of the Space Division at Logica.

Why I Belong to the BIS

"Detailed exploration of Antarctica had to wait two generations after the heroic era of Amundsen and Scott. Similarly, in space. While the emphasis today is on its application in the service of mankind, we may look forward to the long term exploration both of, and from, the Moon.

"The BIS promotes this longer term future of space travel, a role made all the more important by the short term horizons of many of today's planners.

"It deserves the support of everyone interested in man's future in space."

- **Join a worldwide international space organisation with a long history of contributions to space exploration**
- **Membership offers free Evening Lectures and reduced rates to Technical Symposia held by the Society**

JOIN NOW with Special Offer !!

SEND TO: THE BRITISH INTERPLANETARY SOCIETY, 27/29 SOUTH LAMBETH ROAD, LONDON SW8 1SZ, ENGLAND PN

APPLICATION FOR MEMBERSHIP of the BRITISH INTERPLANETARY SOCIETY

The Society was founded in 1933 and is the world's longest-established organisation devoted solely to the exploration of space and astronautics. It has charitable status and obtains most of its income from its membership. It is financially independent.

(A photocopy of this form may be submitted)

I apply for Membership which will include a subscription to *Spaceflight* and one of the following special offers:

a copy of the book by Robert C. Parkinson "Citizens of the Sky" ❐†
or a Society Coat of Arms Embroidered Badge ❐†
or BIS Playing Cards ❐†

I enclose £38 (US$69) for a 12 month subscription from January-December 1998 ❐

A reduced rate of £26 (US$47) is available for those under 22 or of 65 years or over.

Full Name .... Title ....
(Print with surname first)
Postal Address .... Date of Birth ....

....

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Professional Affiliation .... Job Position or Title ....
& Address (if applicable)

....

Signature .... Date ....

Application constitutes acceptance of the Society's Constitutional Rules

7/97

Offer closes 30 June 1998

† While stocks last.